The Adventures of Archibald Higgins

FOR

A FISTFUL

OF AMPERES

The Association Knowledge without Borders, founded and chaired by Professor Jean-Pierre Petit, astrophysicist, aims at spreading scientific and technical knowledge in as many countries as possible and in as many languages as possible. To this end, all his popular scientific works, which cover a period of thirty years, and more particularly the illustrated albums he has created, are now freely accessible. Anyone is now free to duplicate the present file, either in digital form or in the form of printed copies and circulate these copies to libraries , within the context of schools or universities or associations whose aims would be the same as the association , provided that they do not derive any profit from this circulation and that they do not have any political, sectarian or confessional connotations. These pdf files may also be put on line in the computer networks of school and university libraries.

Jean-Pierre Petit intends to create numerous other works which will be accessible to a larger audience. Even illiterate people will be able to read them because the written parts will “speak” when the readers click on them. Thus it will be possible to use these works to support literacy schemes. Other albums will be "bilingual" in so far as it will be possible to switch from one language to another selected language with a mere click. Hence another tool made available to develop language skills.

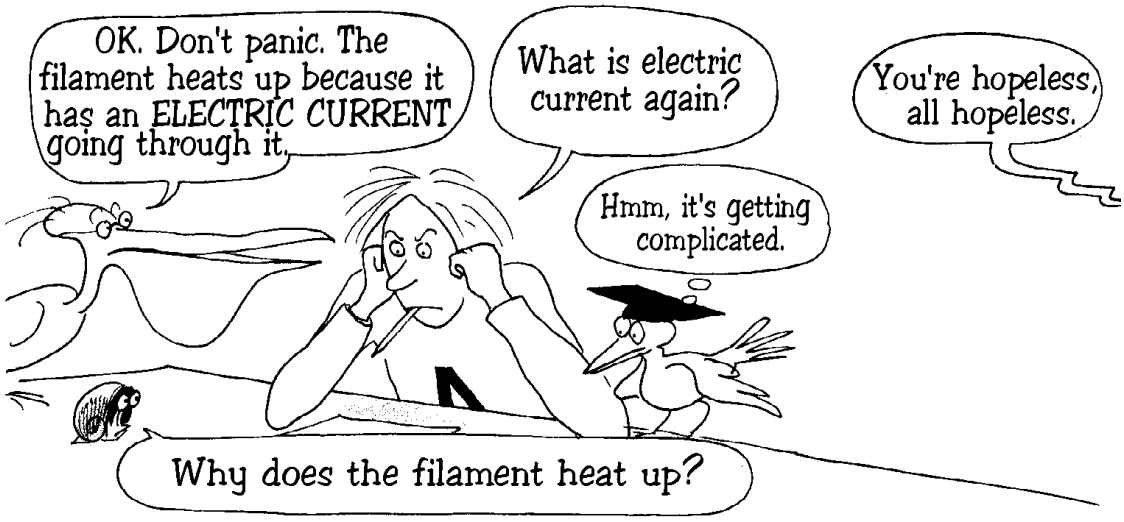
Jean-Pierre Petit was born in 1937. He made his career in French research. He worked as a plasma physicist, he directed a computer science centre, he has created softwares, he has published hundreds of articles in scientific magazines, dealing with subjects ranging from fluid mechanics to theoretical cosmology. He has published about thirty books which have been translated in numerous languages.

The association can be contacted on the following internet site:

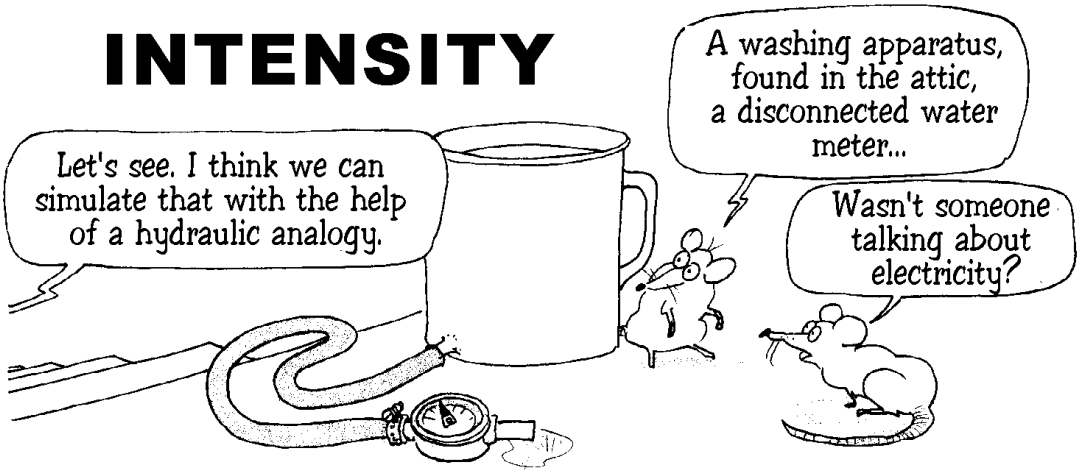
http://savoir-sans-fontieres.com

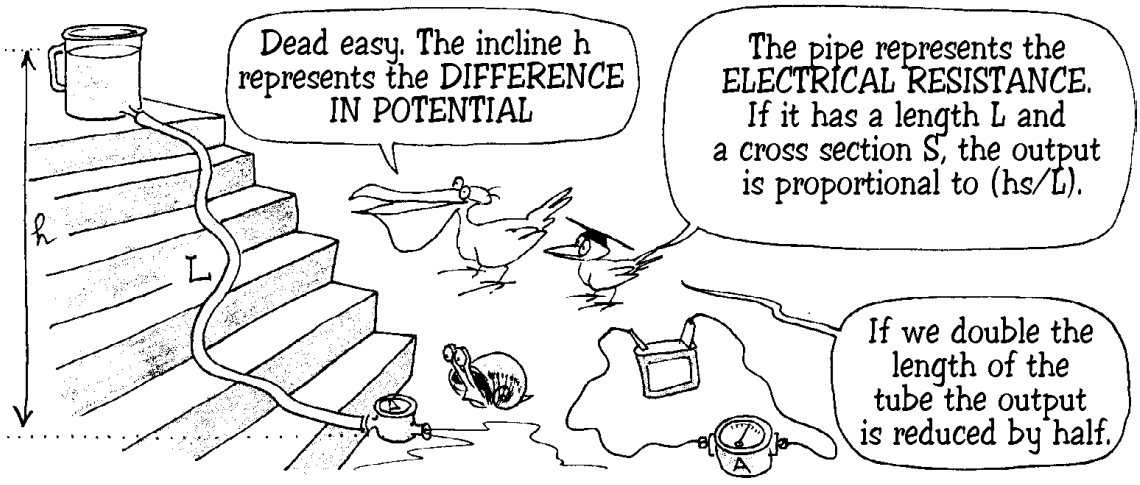
PROLOGUE

(*) New Zealand Physicist, discovered the atom in 1905

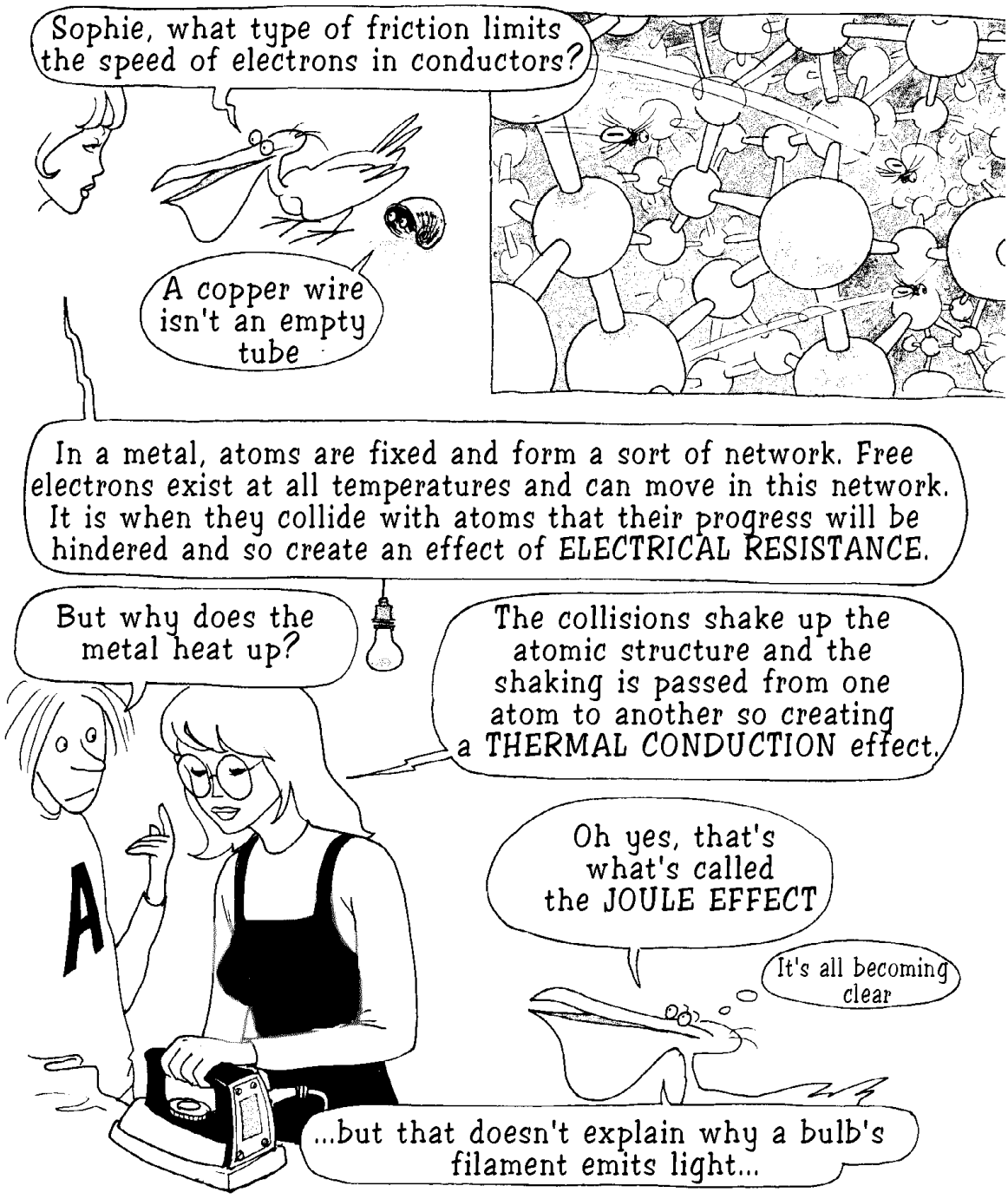

OK. Don't panic. The filament heats up because it has an ELECTRIC CURRENT going through it.
What is electric current again?
You're hopeless, all hopeless.
Hmm, it's getting complicated.
Why does the filament heat up?

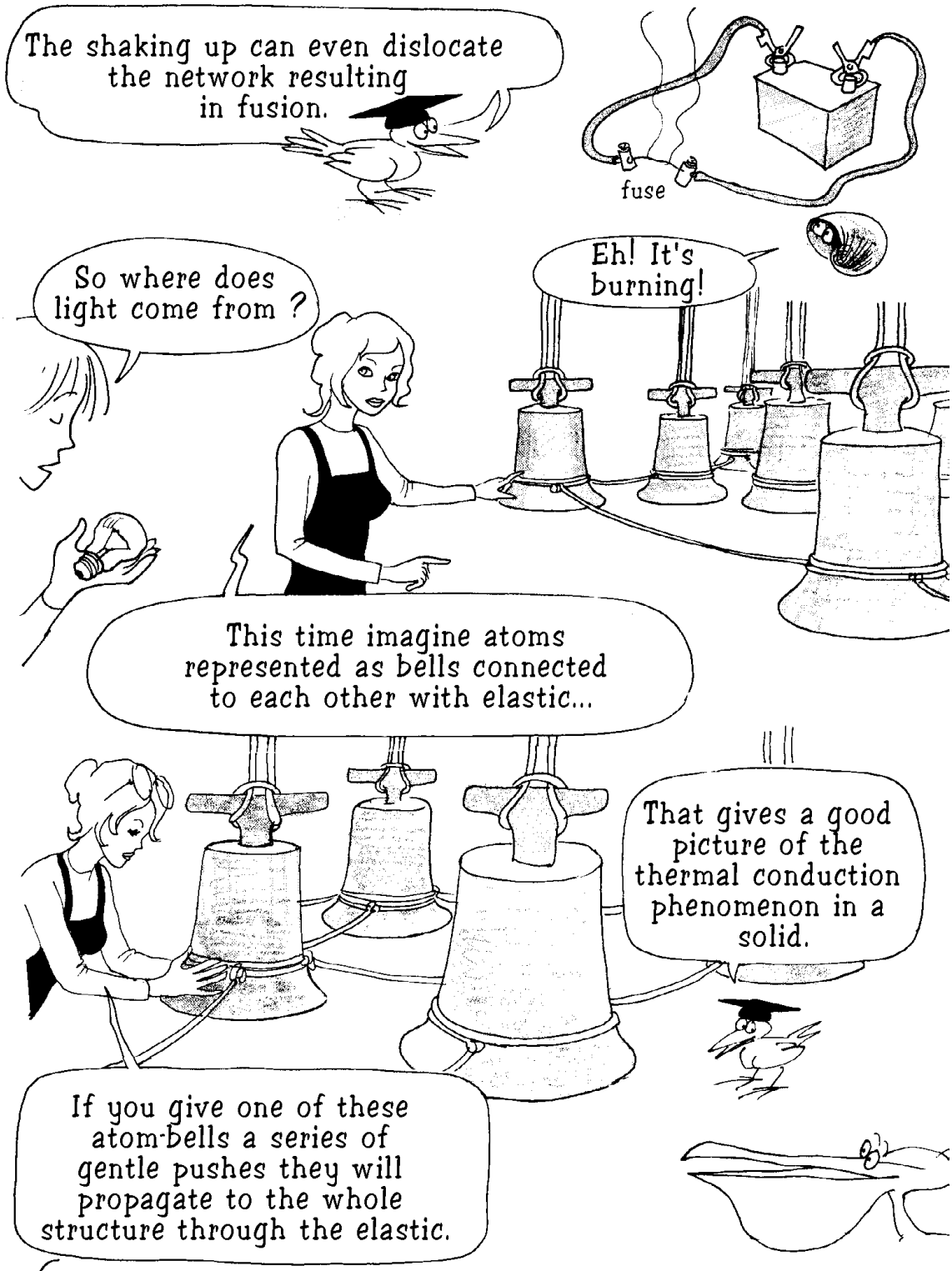
INTENSITY


A washing apparatus, found in the attic, a disconnected water meter...
Let's see. I think we can simulate that with the help of a hydraulic analogy.
Wasn't someone talking about electricity?

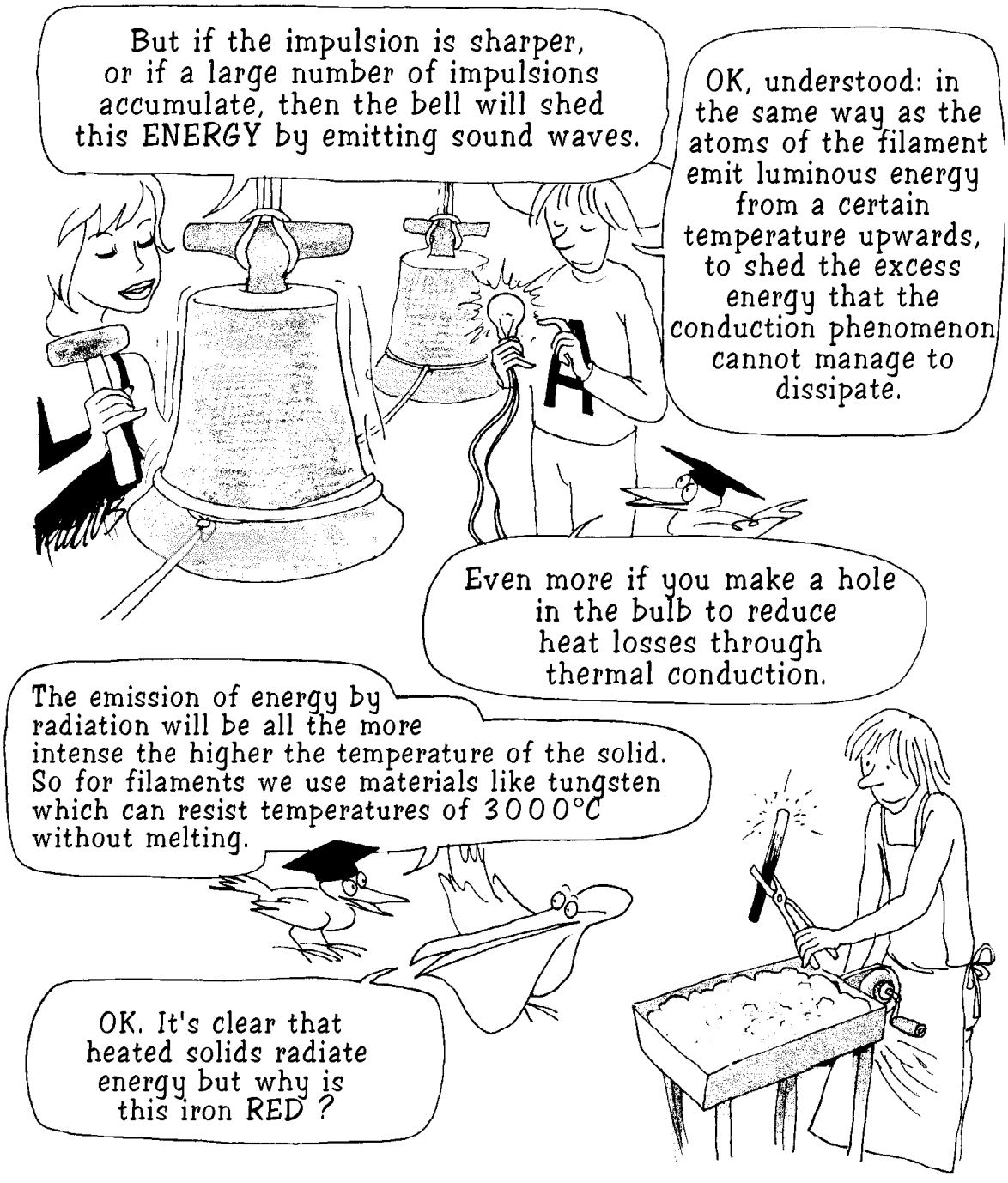

Dead easy. The incline h represents the DIFFERENCE IN POTENTIAL
The pipe represents the ELECTRICAL RESISTANCE. If it has a length L and a cross section S, the output is proportional to (hs/L).
h
L
If we double the length of the tube the output is reduced by half.
A

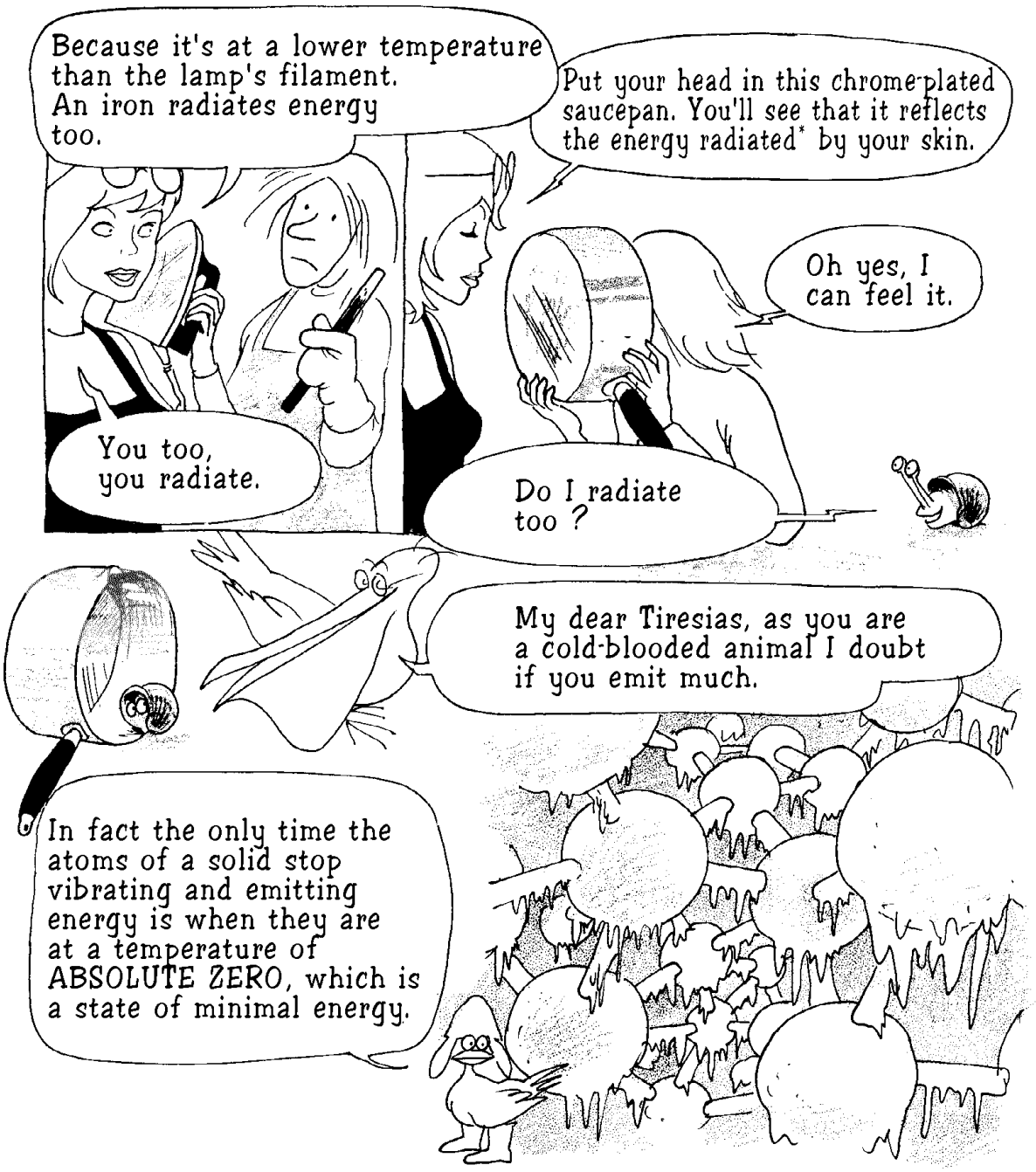
RESISTANCE


Sophie, what type of friction limits the speed of electrons in conductors?
A copper wire isn't an empty tube
In a metal, atoms are fixed and form a sort of network. Free electrons exist at all temperatures and can move in this network. It is when they collide with atoms that their progress will be hindered and so create an effect of ELECTRICAL RESISTANCE.
But why does the metal heat up?
The collisions shake up the atomic structure and the shaking is passed from one atom to another so creating a THERMAL CONDUCTION effect.
Oh yes, that's what's called the JOULE EFFECT
It's all becoming clear
...but that doesn't explain why a bulb's filament emits light...


The shaking up can even dislocate the network resulting in fusion.
fuse
So where does light come from ?
Eh! It's burning!
This time imagine atoms represented as bells connected to each other with elastic...
That gives a good picture of the thermal conduction phenomenon in a solid.
If you give one of these atom-bells a series of gentle pushes they will propagate to the whole structure through the elastic.

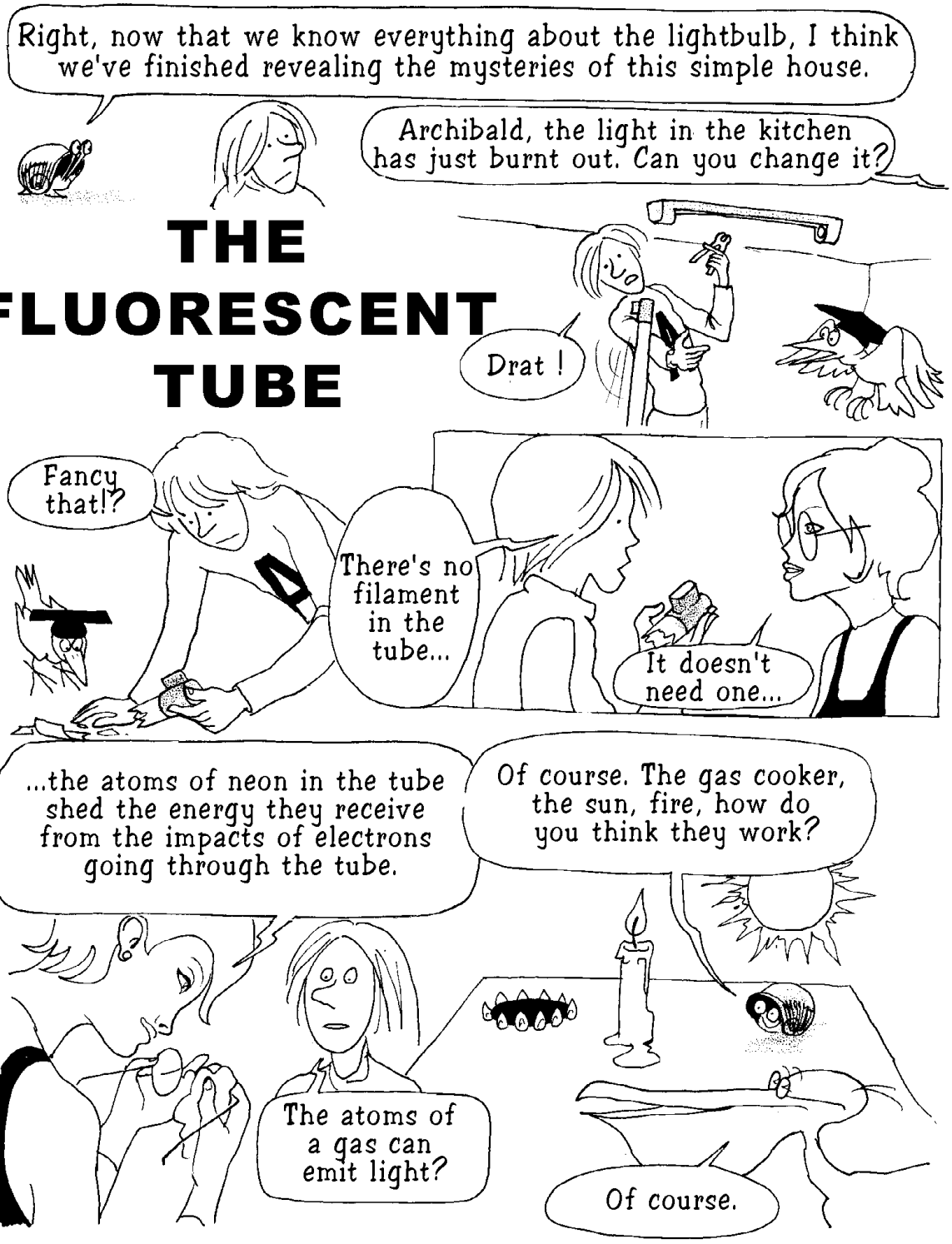
INCANDESCENCE

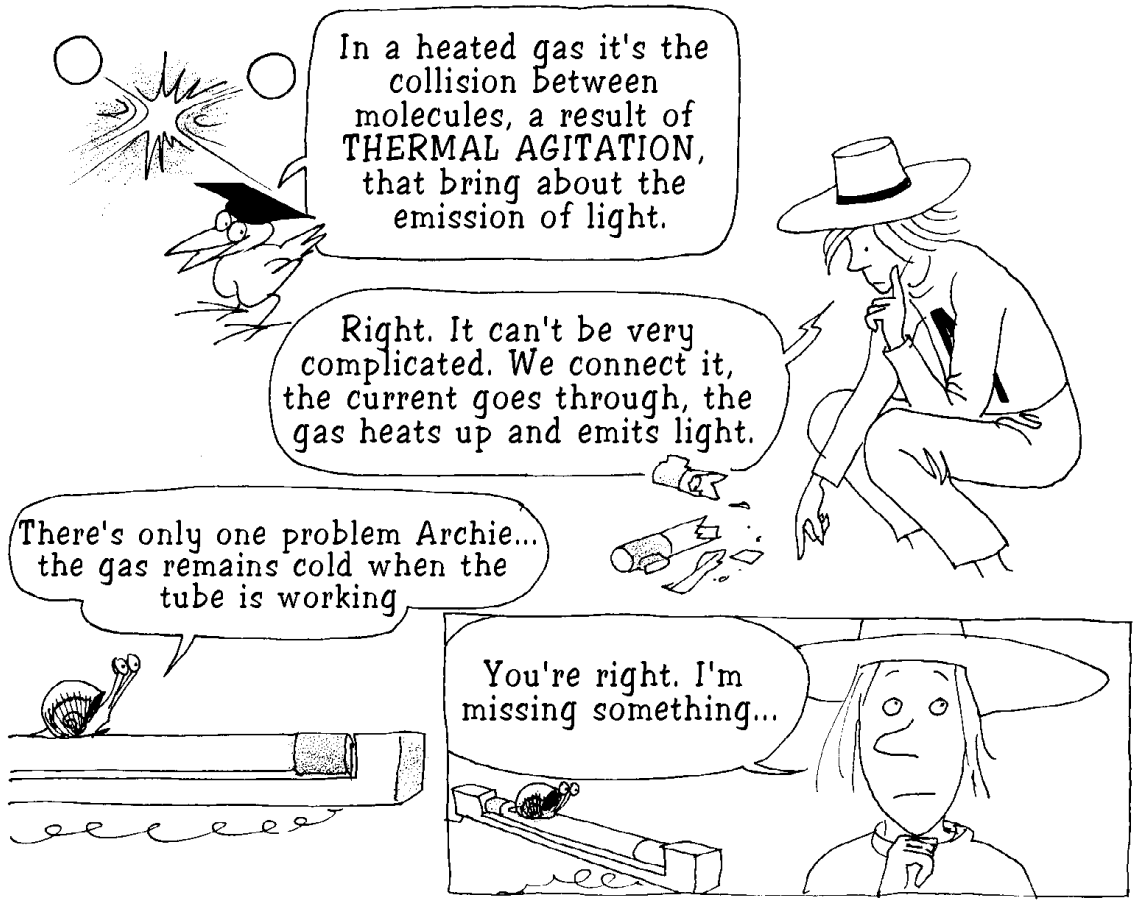




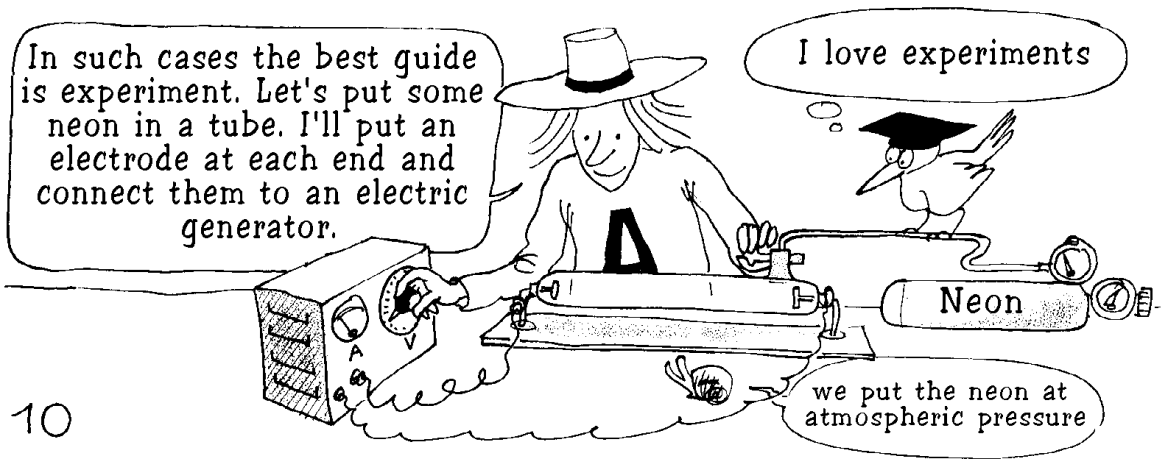
(*) This type of non-visible radiated energy, emitted by medium or low temperature bodies, is called INFRARED energy.

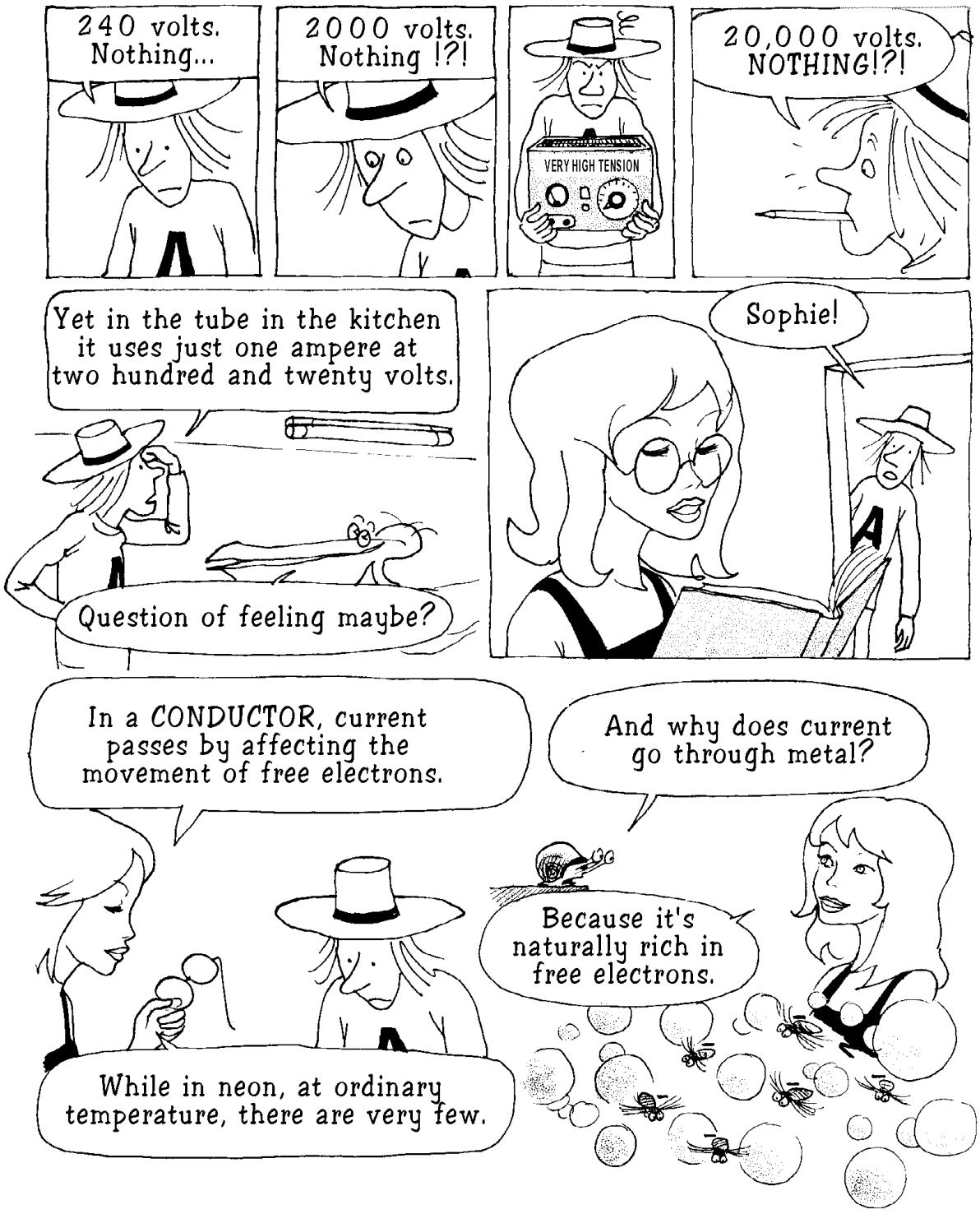
THE FLUORESCENT TUBE





ELECTRIC CONDUCTIVITY




240 volts. Nothing...
2000 volts. Nothing !?!
VERY HIGH TENSION
20,000 volts. NOTHING!?!
Yet in the tube in the kitchen it uses just one ampere at two hundred and twenty volts.
Question of feeling maybe?
Sophie!
In a CONDUCTOR, current passes by affecting the movement of free electrons.
While in neon, at ordinary temperature, there are very few.
And why does current go through metal?
Because it's naturally rich in free electrons.

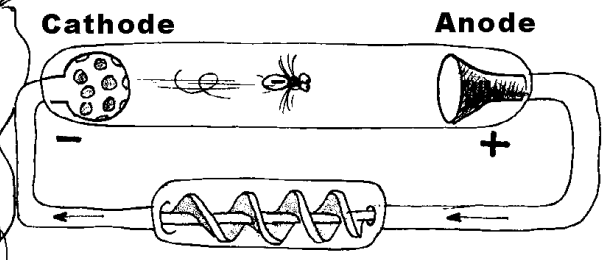
Do you mean that there aren't any electrons in cold gases?

Here are some TIED ELECTRONS.

No, but they're all busy turning on their orbits around the atoms' nucleii

What makes electrons go round?

Their movement is begun by the GENERATOR, which acts like a sort of pump



ELECTRIC GENERATOR

So, what's the problem?

Great, it works.

Tiresias, get out of the way.

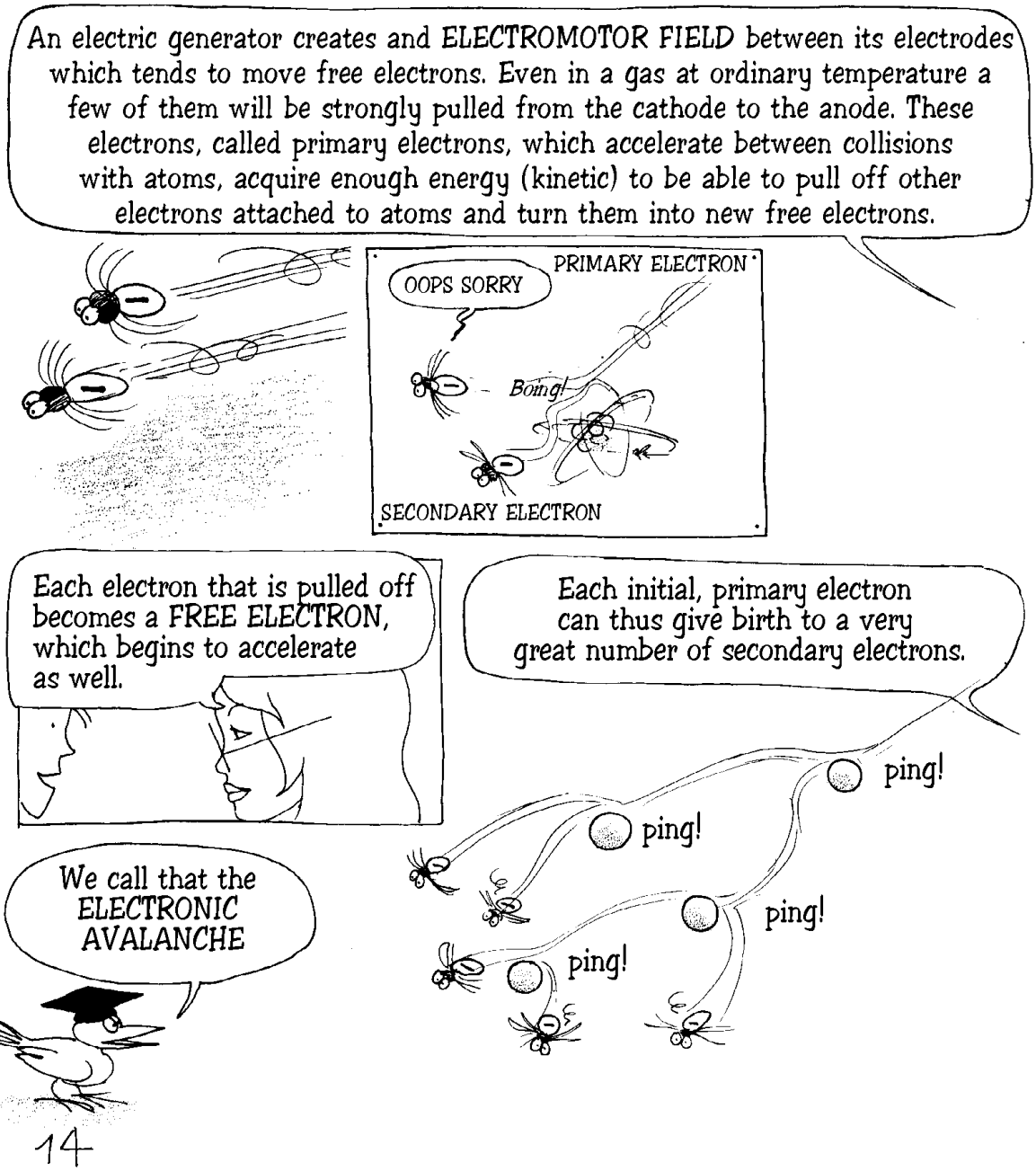
Archibald has found an ELECTRON PUMP.

It's a generator of high voltage direct current.

Ouch!

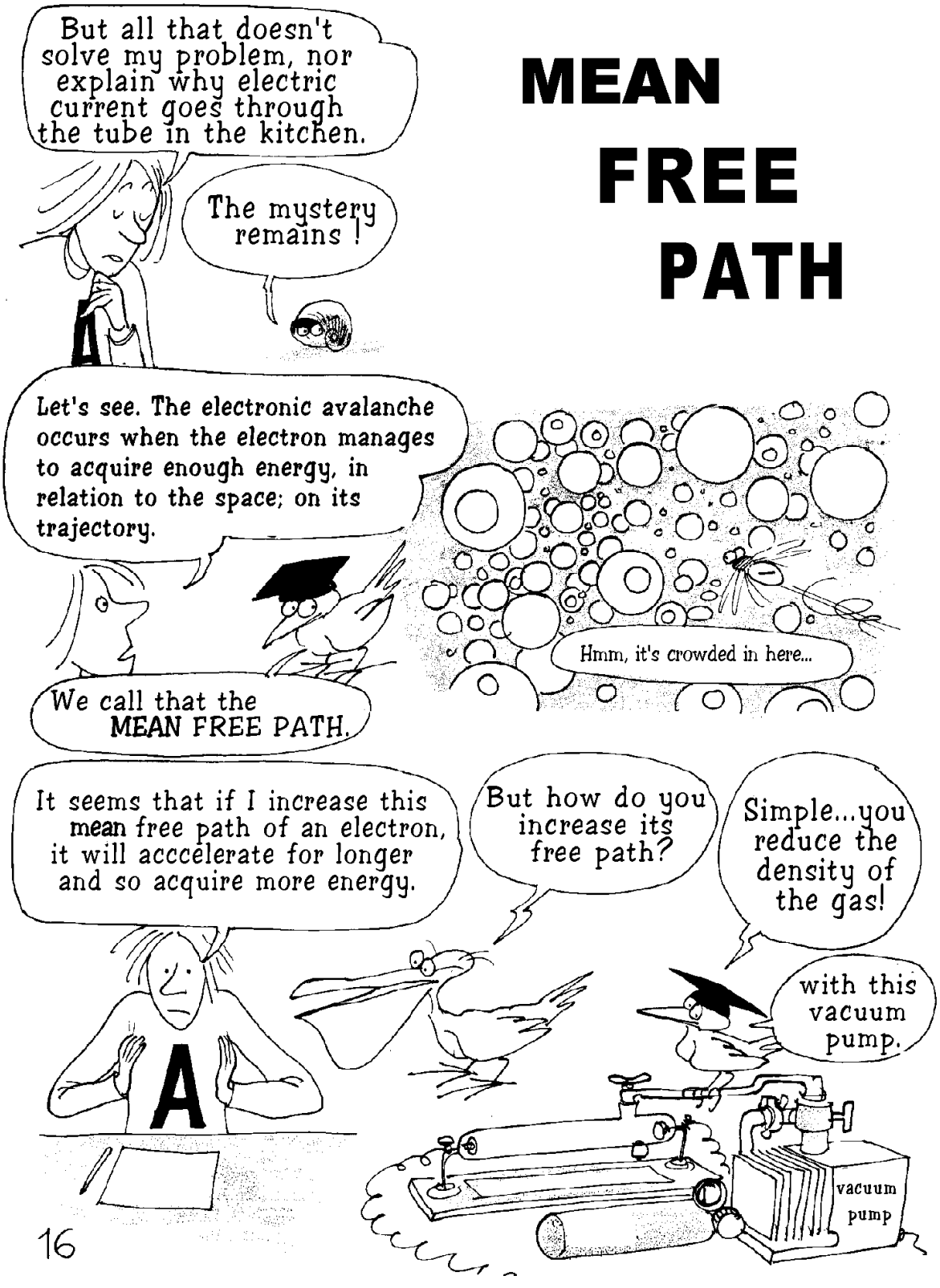
THE ELECTRIC ARC

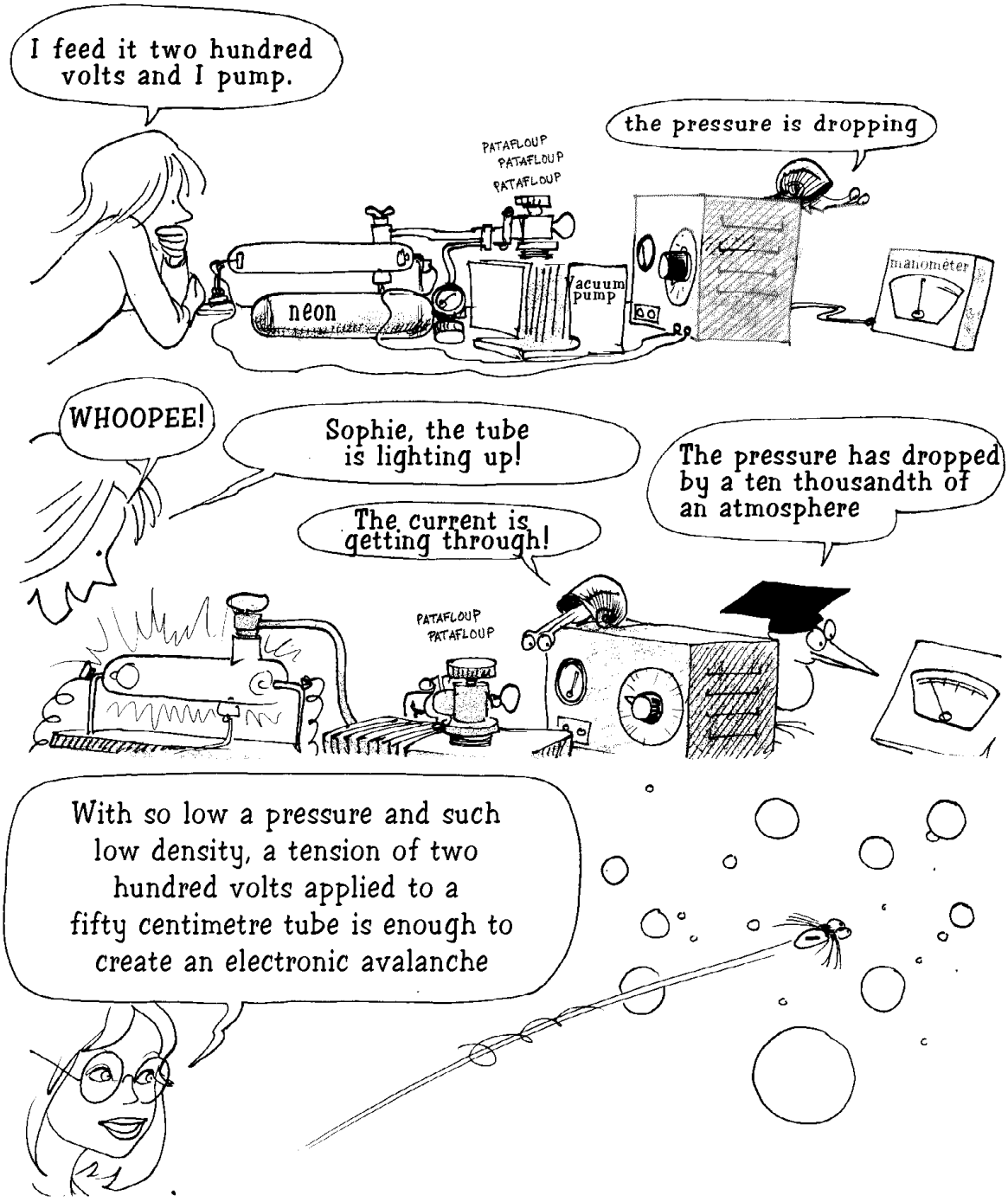
THE ELECTRONIC AVALANCHE



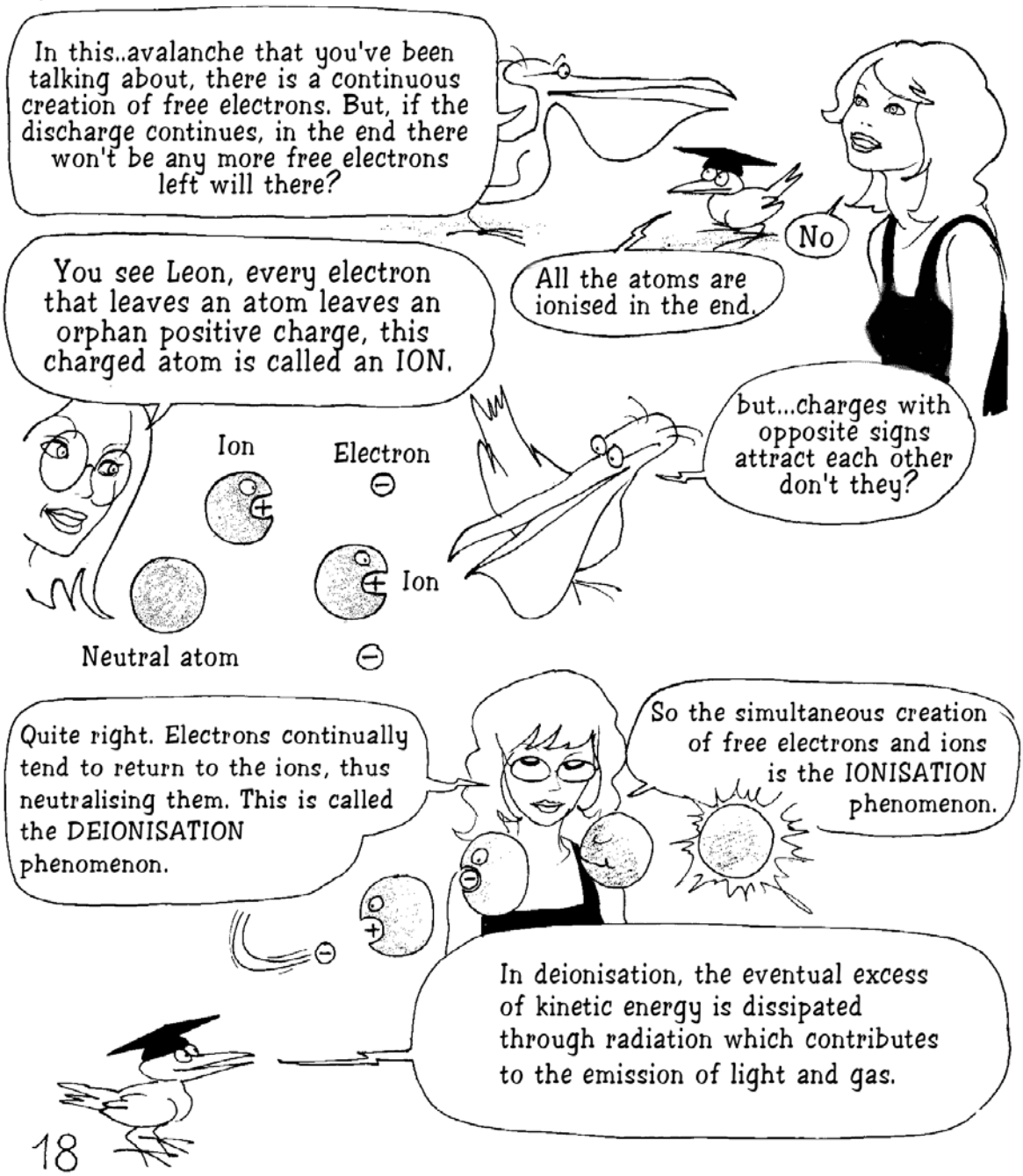

In the previous experiment this was shown by a sudden rise in intensity in the electron flow.
In other words, the gaz between the electrons had suddenly become very conductive. The generator, placed in a short-circuit situation, burnt out.
In air the RELEASE happens when, at atmospheric pressure, the difference of potential reaches 30,000 volts per centimetre.
Hmm, It's getting cloudy.
BOUM !
LIGHTNING is an electric arc that is created when the difference in potential between a cloud and the earth passes this point of release.
How can electricity make such a lot of noise?
In an electric arc there is a violent release of heat which creates a SHOCKWAVE.

MEAN FREE PATH




I feed it two hundred volts and I pump.
the pressure is dropping
PATAFLOUP
PATAFLOUP
PATAFLOUP
neon
vacuum pump
manometer
WHOOPEE!
Sophie, the tube is lighting up!
The current is getting through!
The pressure has dropped by a ten thousandth of an atmosphere
PATAFLOUP
PATAFLOUP
With so low a pressure and such low density, a tension of two hundred volts applied to a fifty centimetre tube is enough to create an electronic avalanche

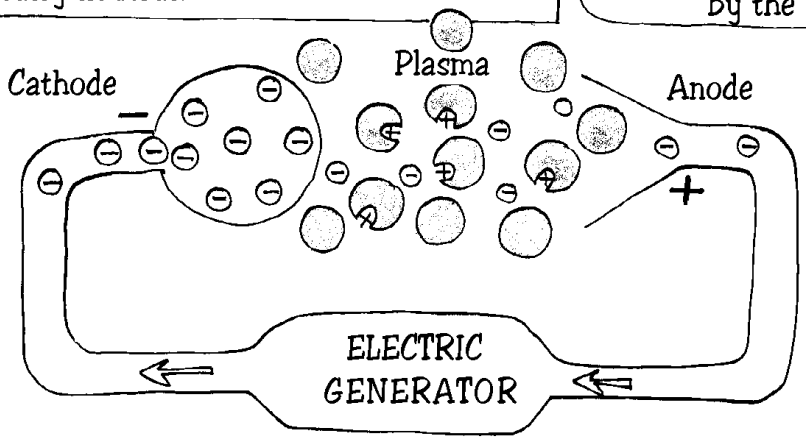
IONISATION
DE-IONISATION



PLASMA

Let's recapitulate: A sort of electron pump, called an electric generator enriches a CATHODE with electrons. This cathodic charge acts on the electrons in a gas, accelerates them and continually creates new free electrons by an electronic avalanche effect. When the IONISATION and DEIONISATION phenomenan balance out, we get a mix of ions that we call plasma, electrically neutral.

The current of electrons circulates. They are emitted by the cathode and collected by the anode.



Goodness. So when I turn on a fluorescent light I'm creating PLASMA!

It's amazing what you can find in a house!

Plasma!

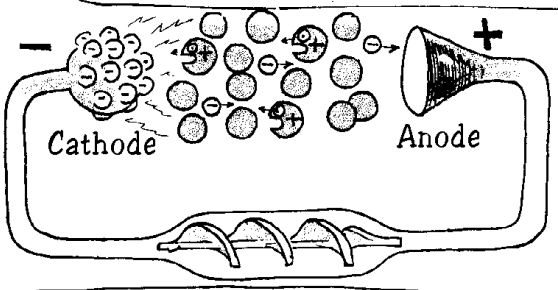
A working fluorescent tube contains plasma. Max says that the sun is also plasma, a big ball of ionised gas. But why is the sun hot and the fluorescent tube is cold?

In this type of 'cold' plasma it's the collisions between electrons and atoms that keep the ionisation going, whereas in the sun it is collisions between atoms. They are necessarily in a state of agitation so the gaz is hot.

In the fluorescent tube we have NON-THERMIC IONISATION

But in this plasma there are two type of charge, electrons and ions. In theory electric force acts on them both doesn't it?

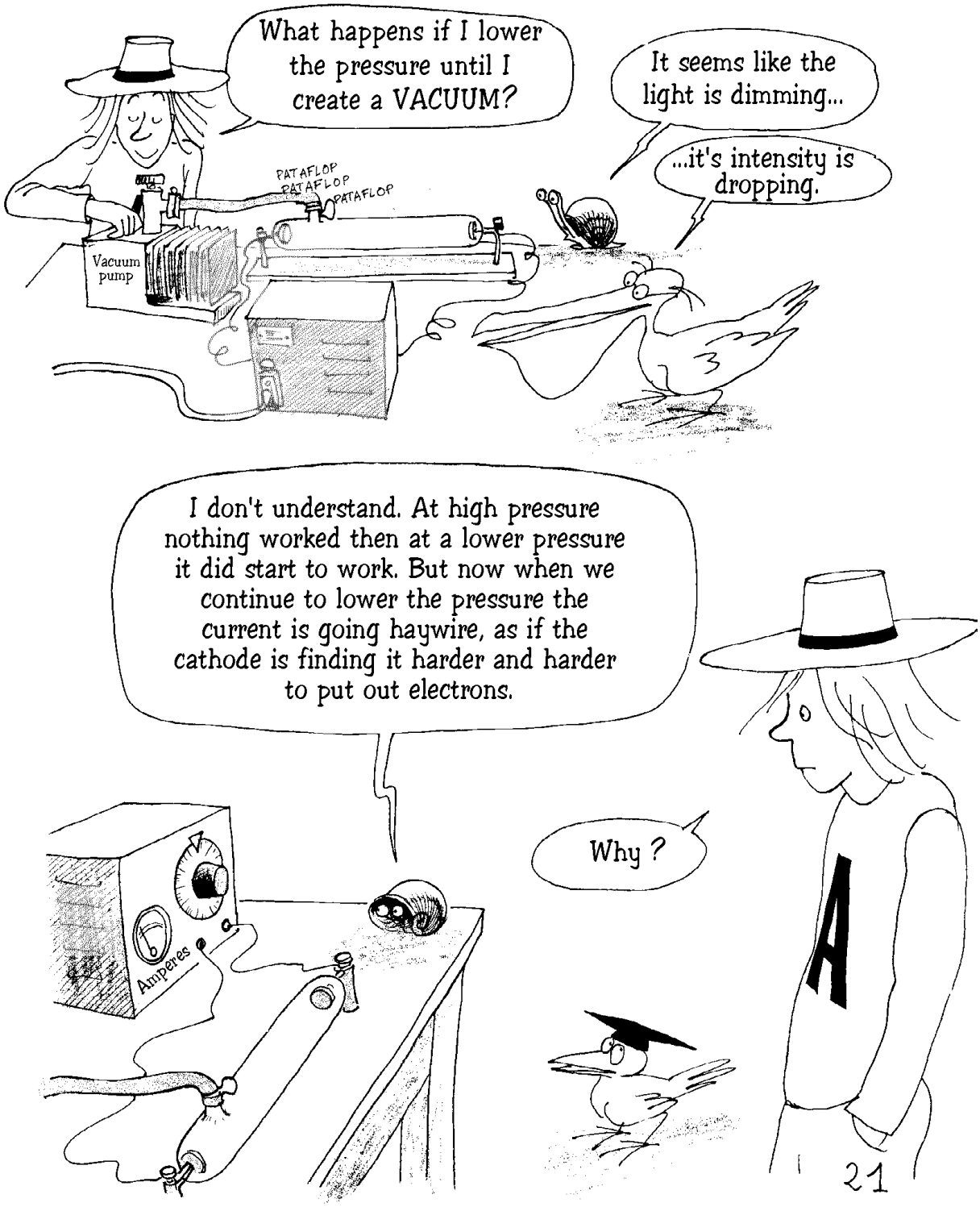
Yes. The electric field in the tube that starts moving electrons pulls them in one direction and ions in the other. The field is due to the accumulation of electrons in the cathode because of the electronic "pressure".

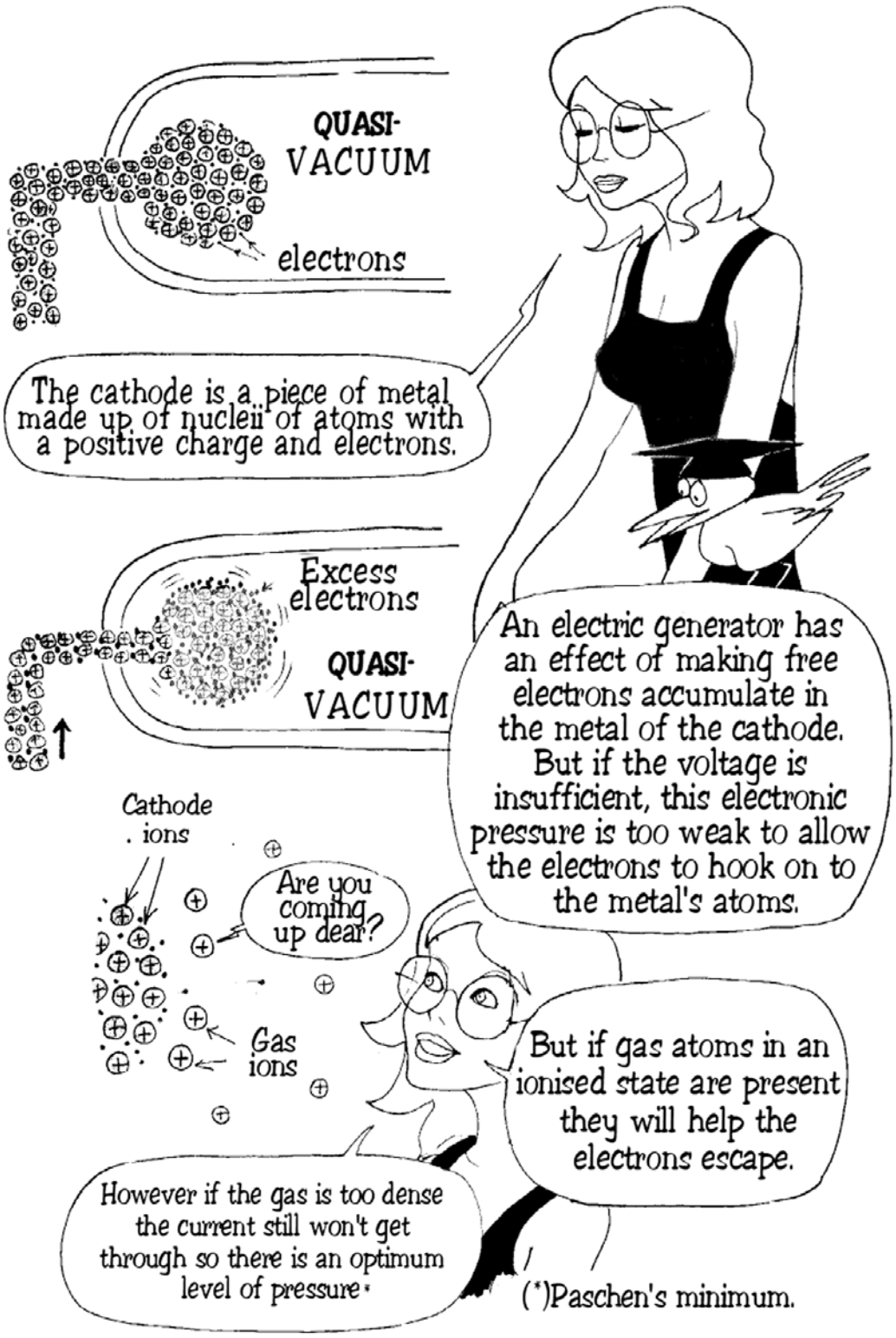


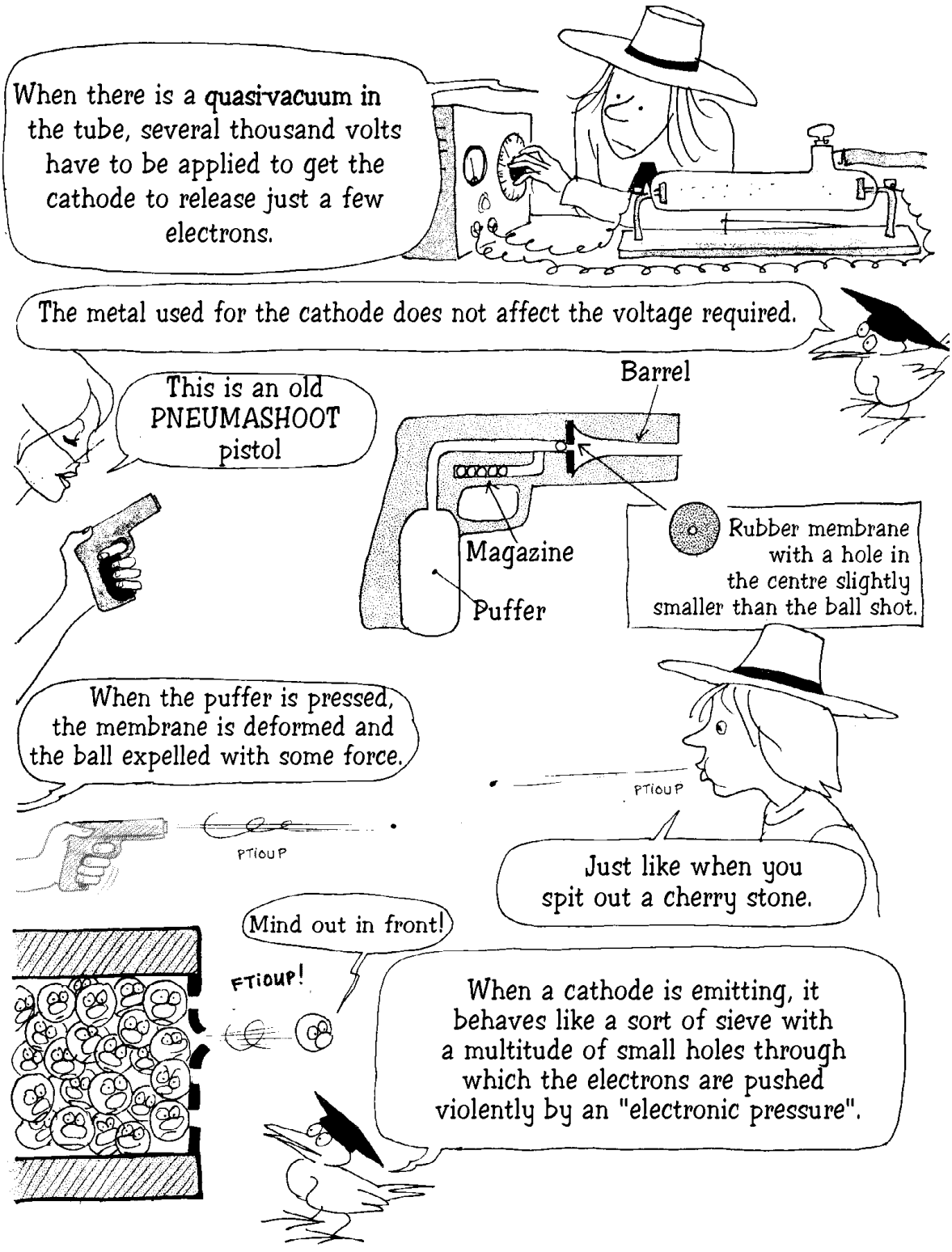
Collisions with neutral atoms slow the progress of the charges. Only electrons, light and mobile, manage to make their way through the disorder.

Which means that in a fluorescent tube the IONIC CURRENT remains negligable compared with the ELECTRIC CURRENT.

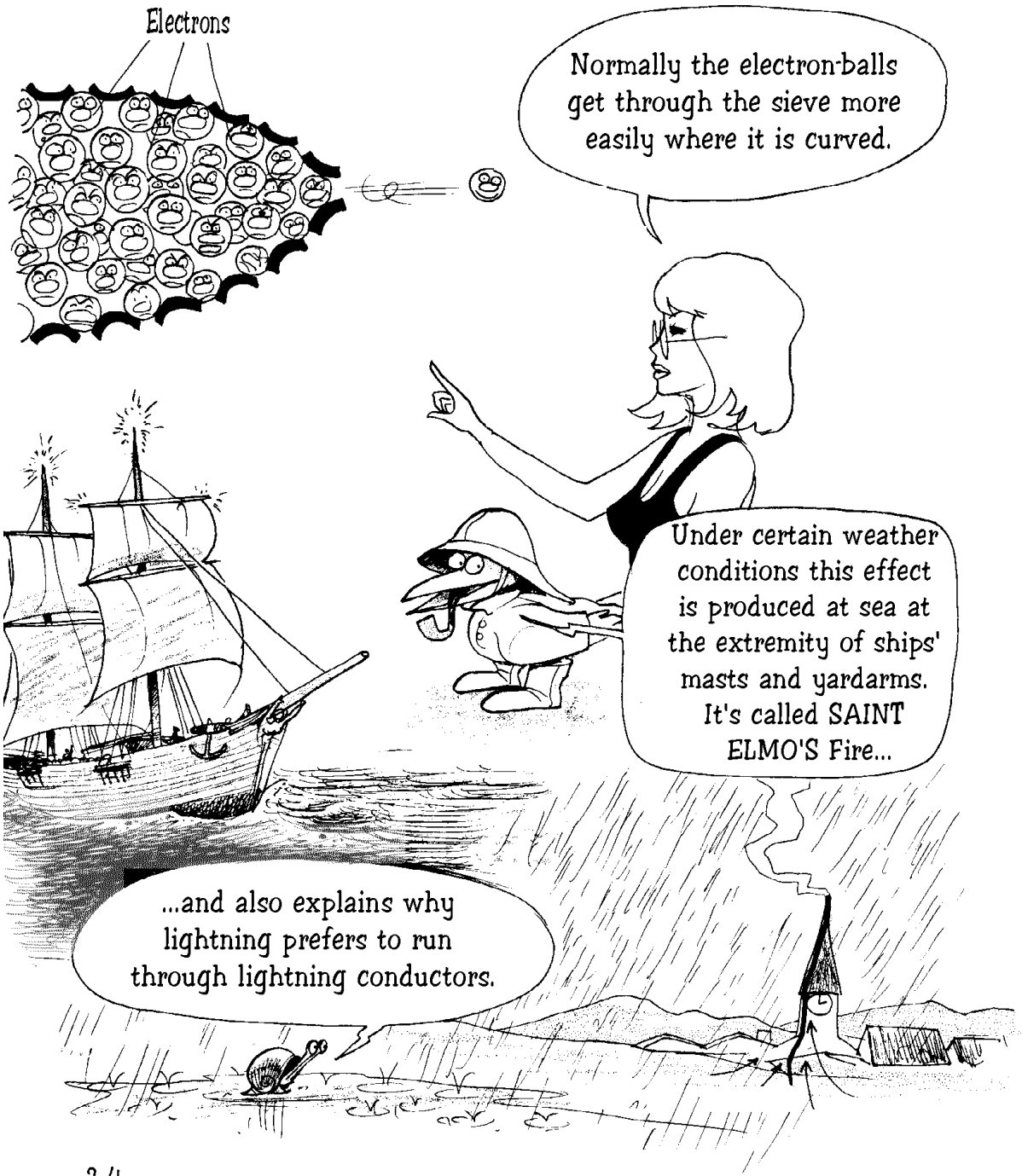
CATHODIC EMISSION

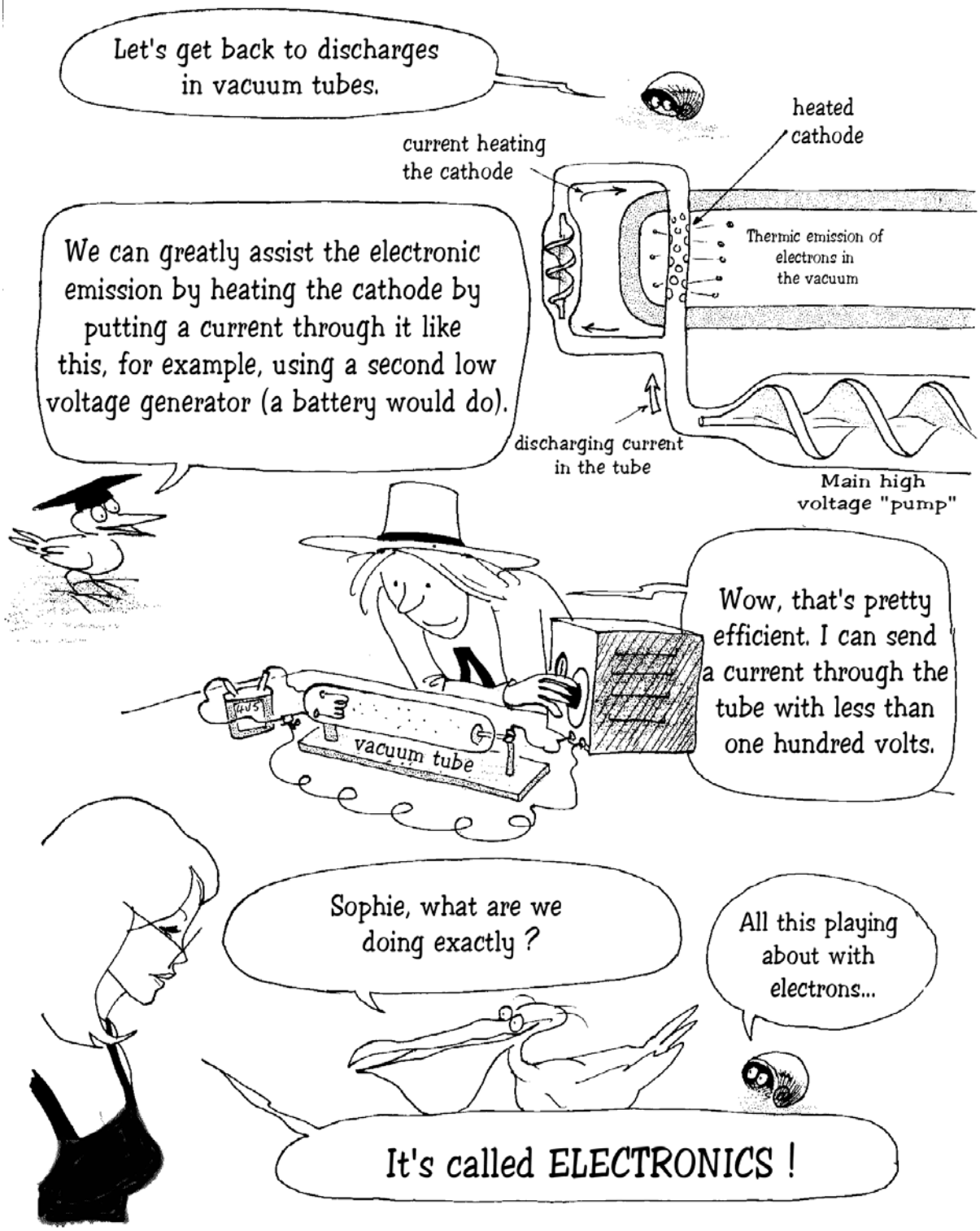


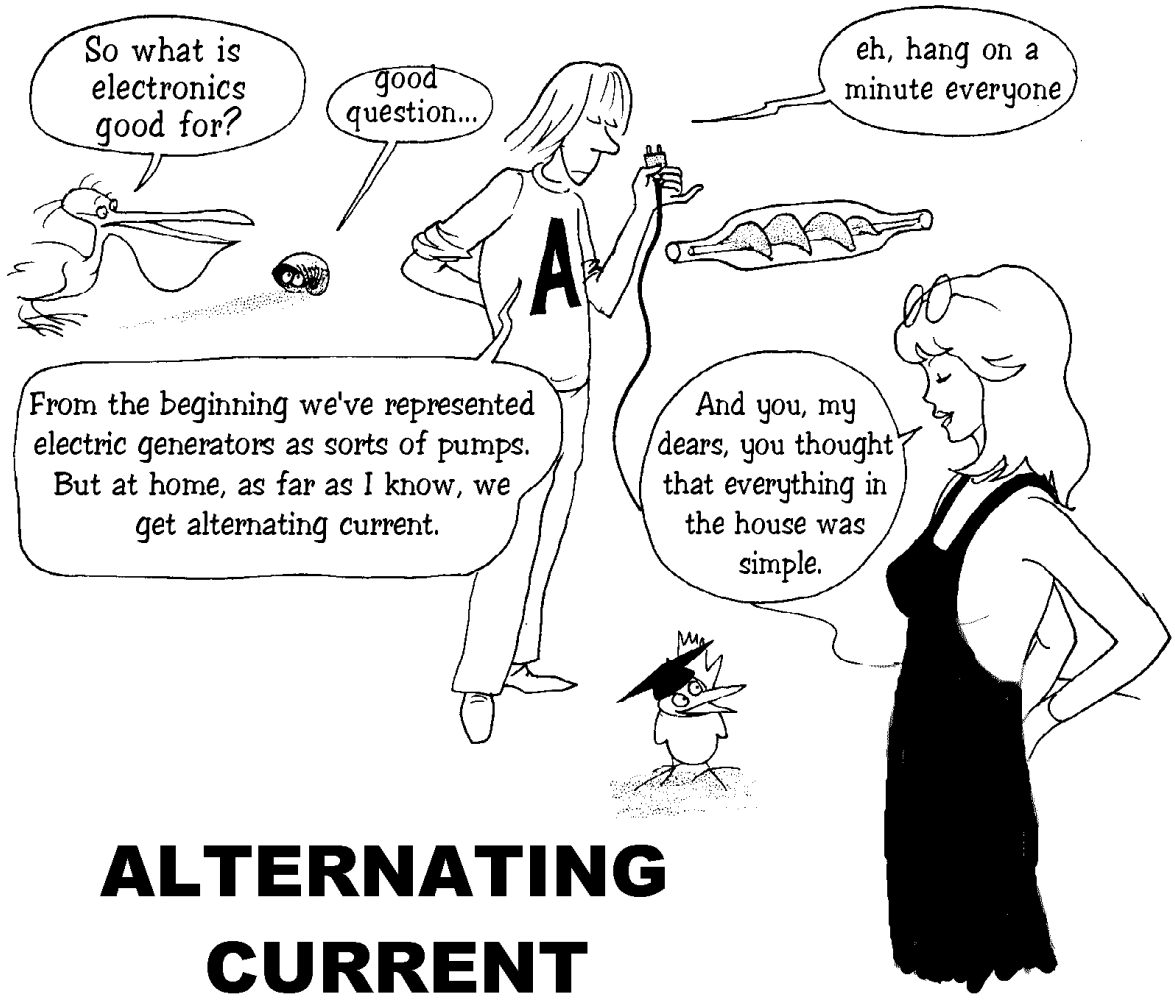

QUASI-
VACUUM
electrons
The cathode is a piece of metal made up of nuclei of atoms with a positive charge and electrons.
Excess electrons
QUASI-
VACUUM
An electric generator has an effect of making free electrons accumulate in the metal of the cathode. But if the voltage is insufficient, this electronic pressure is too weak to allow the electrons to hook on to the metal's atoms.
Cathode
. ions
Are you coming up dear?
Gas ions
But if gas atoms in an ionised state are present they will help the electrons escape.
However if the gas is too dense the current still won't get through so there is an optimum level of pressure.
(*)Paschen's minimum.


When there is a quasi-vacuum in the tube, several thousand volts have to be applied to get the cathode to release just a few electrons.
The metal used for the cathode does not affect the voltage required.
This is an old PNEUMASHOOT pistol
Barrel
Magazine
Puffer
Rubber membrane with a hole in the centre slightly smaller than the ball shot.
When the puffer is pressed, the membrane is deformed and the ball expelled with some force.
PTIOUP
PTIOUP
Just like when you spit out a cherry stone.
Mind out in front!
FTIOUP!
When a cathode is emitting, it behaves like a sort of sieve with a multitude of small holes through which the electrons are pushed violently by an "electronic pressure".

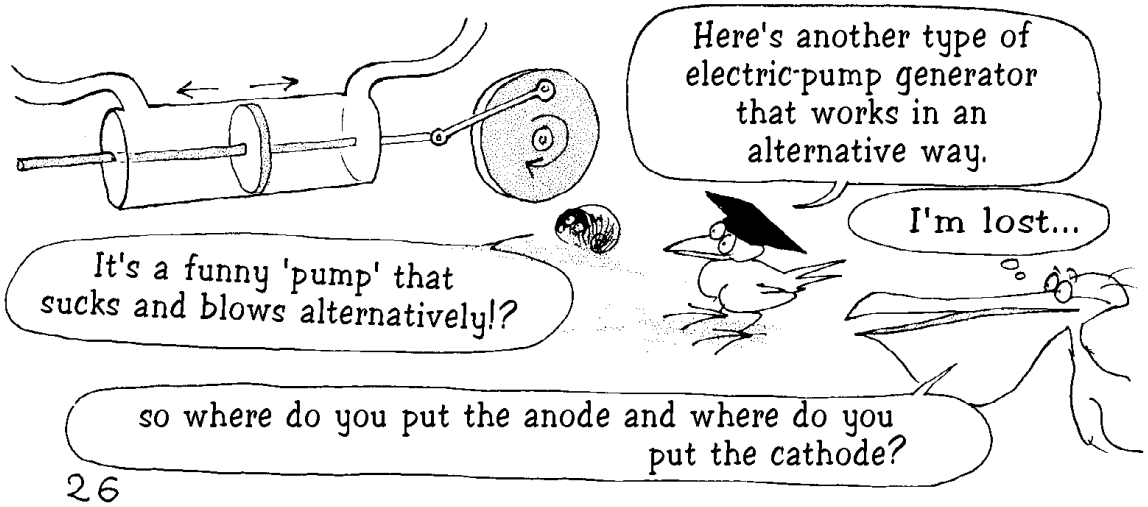
THE POINTS EFFECT

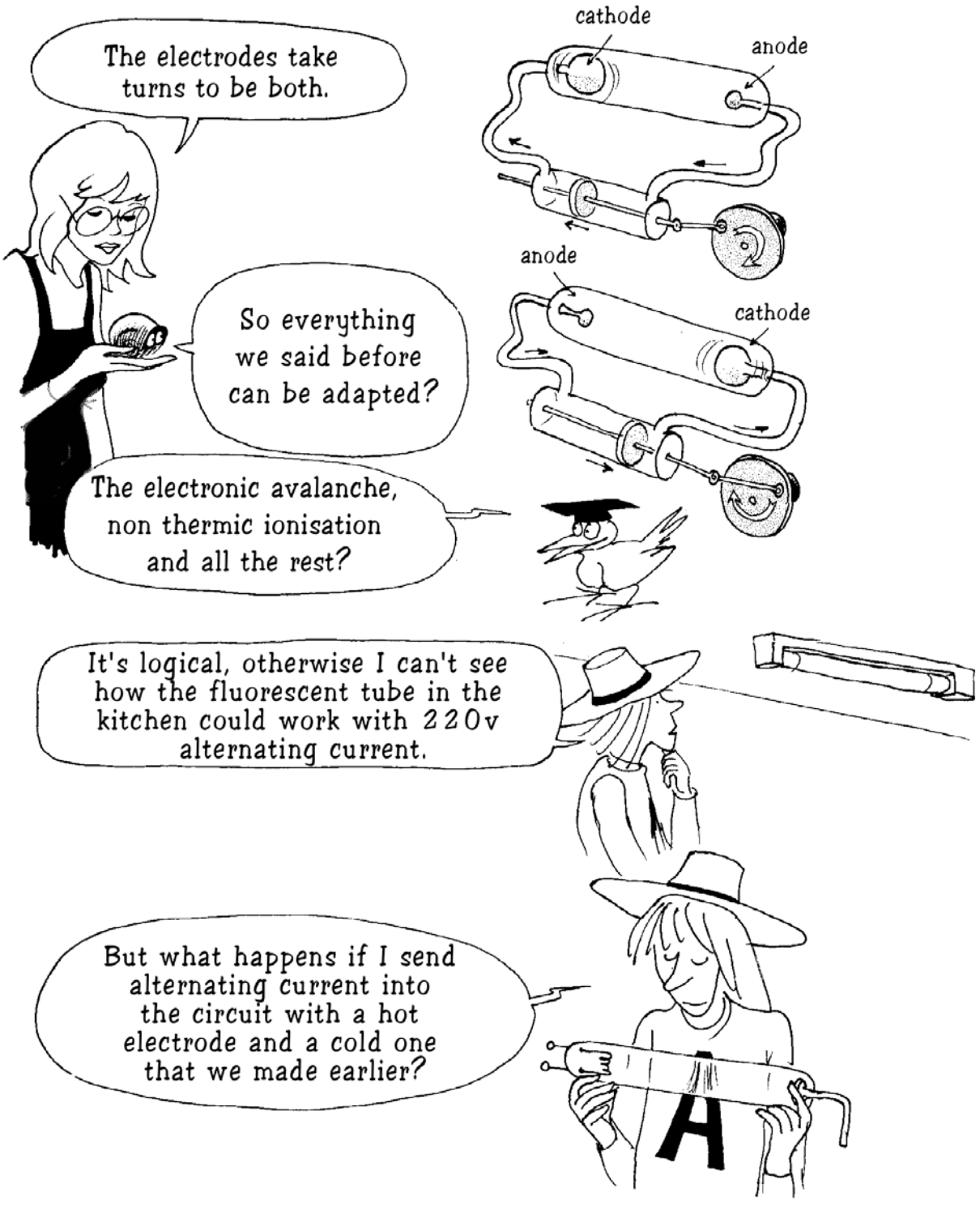


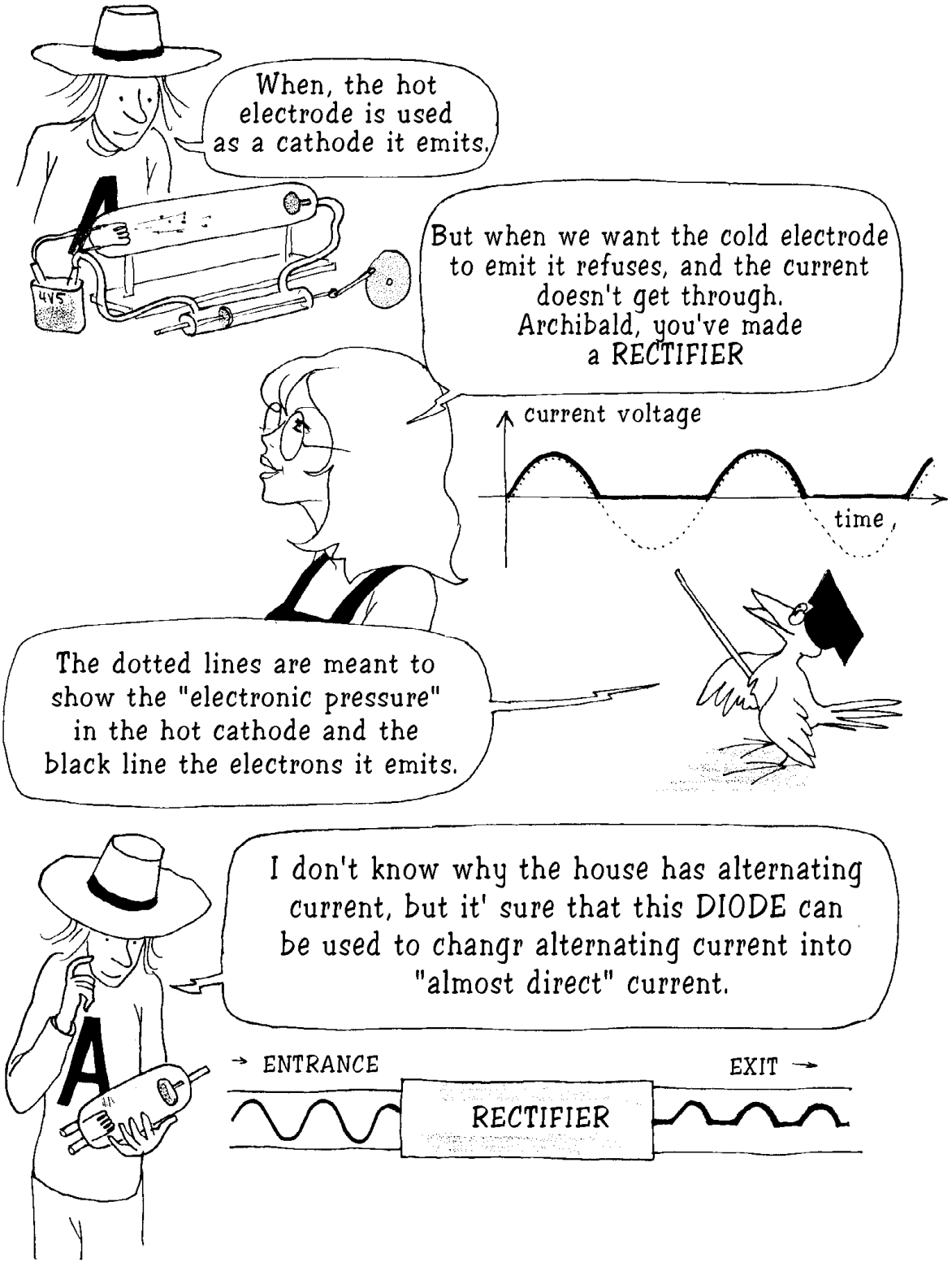

Let's get back to discharges in vacuum tubes.
heated cathode
current heating the cathode
Thermic emission of electrons in the vacuum
We can greatly assist the electronic emission by heating the cathode by putting a current through it like this, for example, using a second low voltage generator (a battery would do).
discharging current in the tube
Main high voltage "pump"
Wow, that's pretty efficient. I can send a current through the tube with less than one hundred volts.
vacuum tube
Sophie, what are we doing exactly ?
All this playing about with electrons...
It's called ELECTRONICS !



ALTERNATING CURRENT

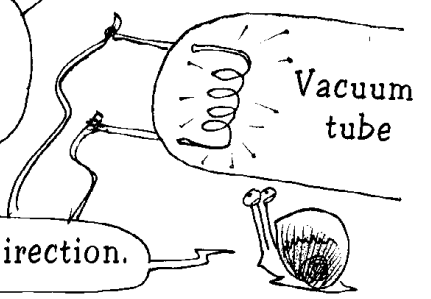



The electrodes take turns to be both.
So everything we said before can be adapted?
The electronic avalanche, non thermic ionisation and all the rest?
It's logical, otherwise I can't see how the fluorescent tube in the kitchen could work with 220v alternating current.
But what happens if I send alternating current into the circuit with a hot electrode and a cold one that we made earlier?
cathode
anode
anode
cathode
A

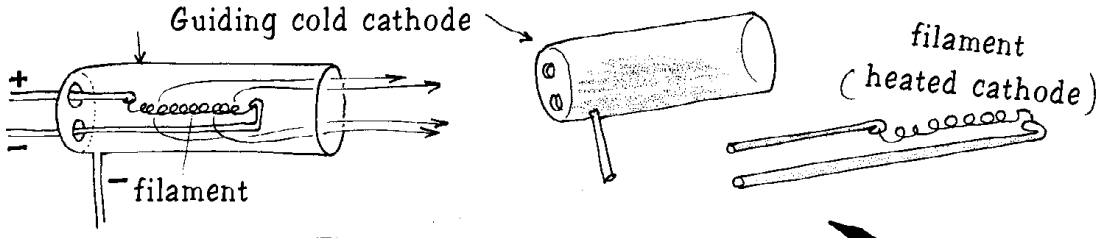

When, the hot electrode is used as a cathode it emits.
But when we want the cold electrode to emit it refuses, and the current doesn't get through. Archibald, you've made a RECTIFIER
current voltage
time
The dotted lines are meant to show the "electronic pressure" in the hot cathode and the black line the electrons it emits.
I don't know why the house has alternating current, but it' sure that this DIODE can be used to changr alternating current into "almost direct" current.
ENTRANCE
EXIT
RECTIFIER

THE ELECTRON GUN

So, there are two sorts of cathodes but only hot cathodes can emit electrons, produce a current. The cold cathode can only carry negative charges.

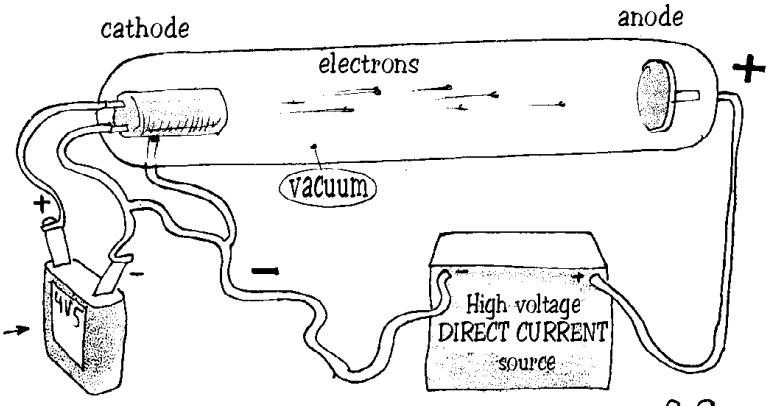


Your hot cathode emits electrons in every direction.



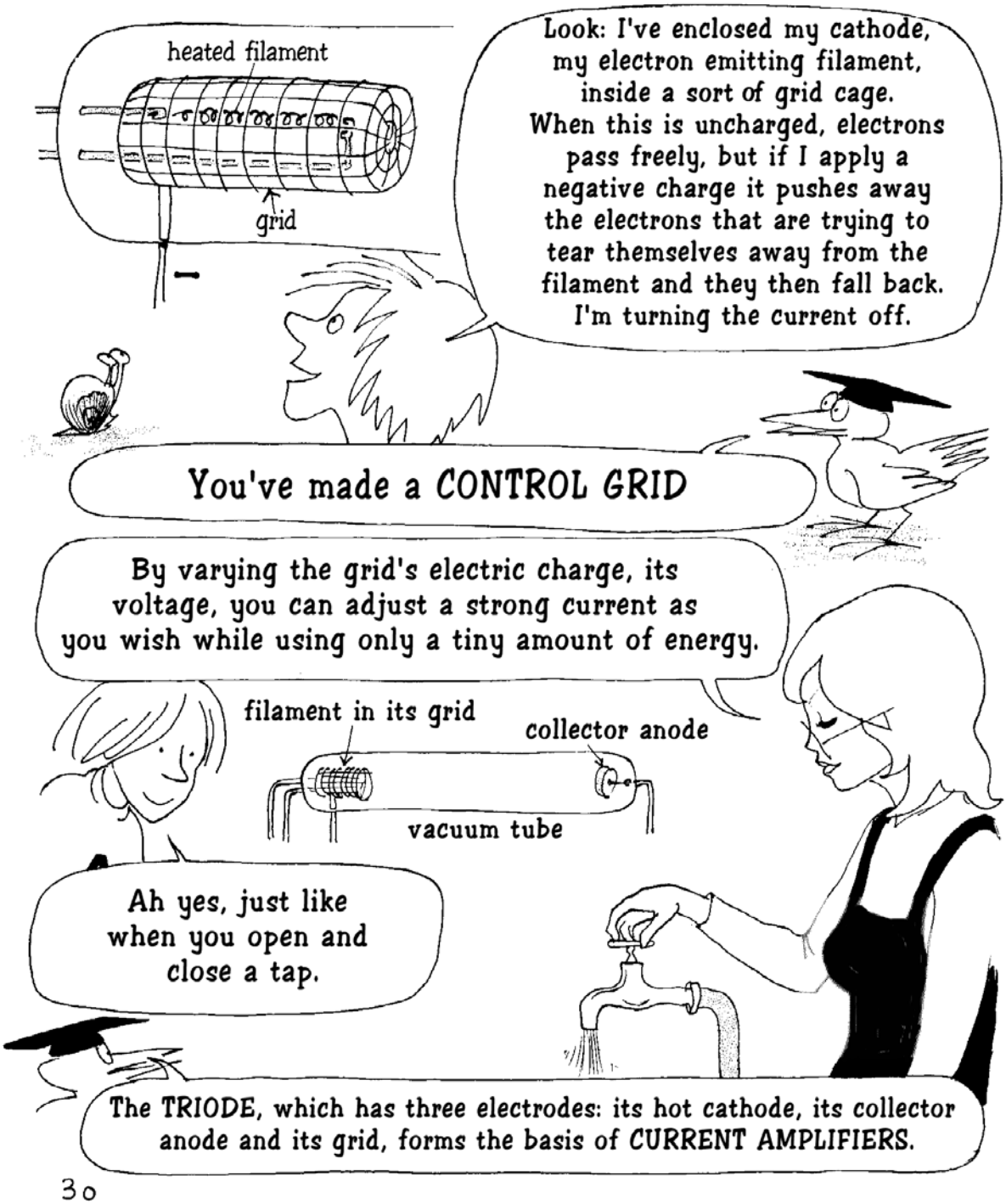
With this cold cathode, whose current output is infinitesmal, Archibald is obliging the electrons emitted by the hot cathode to come out according to the axis of the ELECTRON GUN. Their only way out.

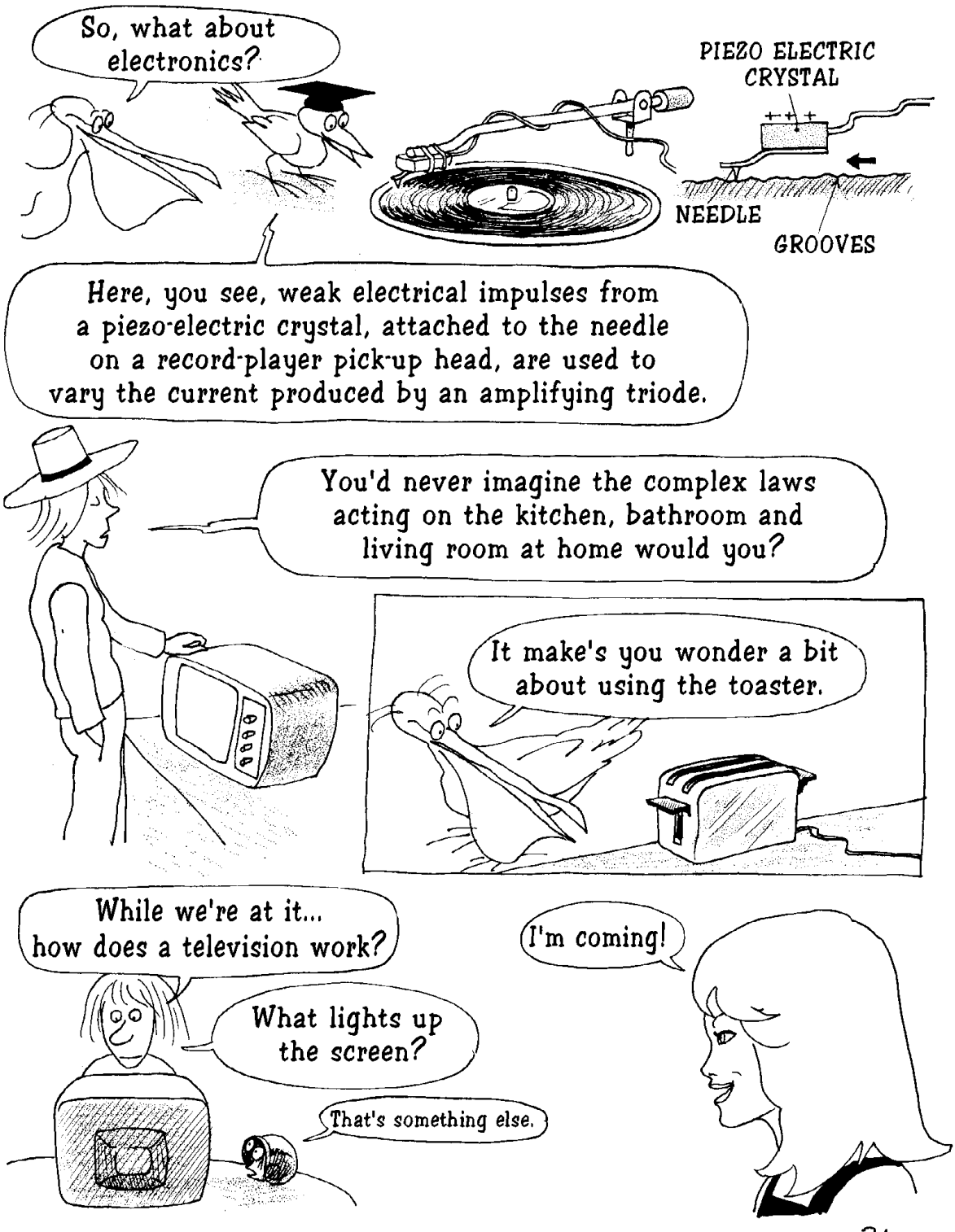
So here it all is inside a vacuum tube



Low-voltage source to heat the filament-cathode.

THE TRIODE

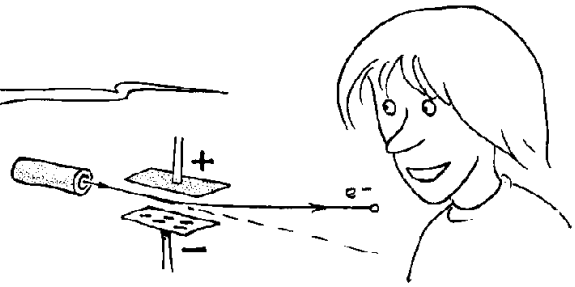

heated filament
grid
Look: I've enclosed my cathode, my electron emitting filament, inside a sort of grid cage. When this is uncharged, electrons pass freely, but if I apply a negative charge it pushes away the electrons that are trying to tear themselves away from the filament and they then fall back. I'm turning the current off.
You've made a CONTROL GRID
By varying the grid's electric charge, its voltage, you can adjust a strong current as you wish while using only a tiny amount of energy.
filament in its grid
collector anode
vacuum tube
Ah yes, just like when you open and close a tap.
The TRIODE, which has three electrodes: its hot cathode, its collector anode and its grid, forms the basis of CURRENT AMPLIFIERS.


So, what about electronics?
PIEZO ELECTRIC CRYSTAL
NEEDLE
GROOVES
Here, you see, weak electrical impulses from a piezo-electric crystal, attached to the needle on a record-player pick-up head, are used to vary the current produced by an amplifying triode.
You'd never imagine the complex laws acting on the kitchen, bathroom and living room at home would you?
It make's you wonder a bit about using the toaster.
While we're at it... how does a television work?
What lights up the screen?
That's something else.
I'm coming!

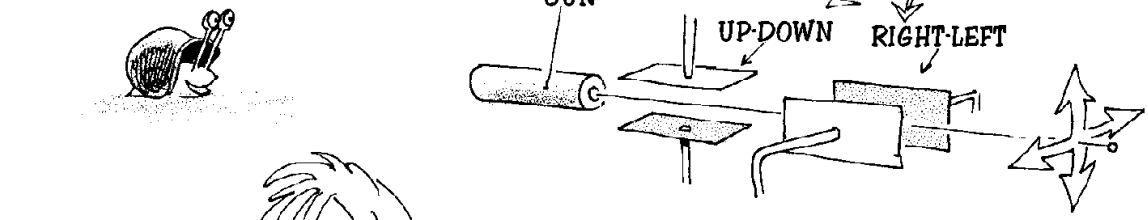
FLUORESCENCE


I've put a touch of a fluorescent product on the inside face of the bell. The pump is underneath.
I can see the cathode electron-gun and the collector anode.
VACUUM PUMP
Generator
Nice equipment
we create a vacuum and...well I never!?!
the electrons don't seem to care where the anode is.
bing
Remember the air-pistol we used earlier. The cathode ejects electrons at high speed and with high kinetic energy, against which the attractive power of the anode doesn't count for much.
But in the end the electrons will have to be collected by the anode.
They'll slowly flow towards it after losing their energy when hitting the bell jar.

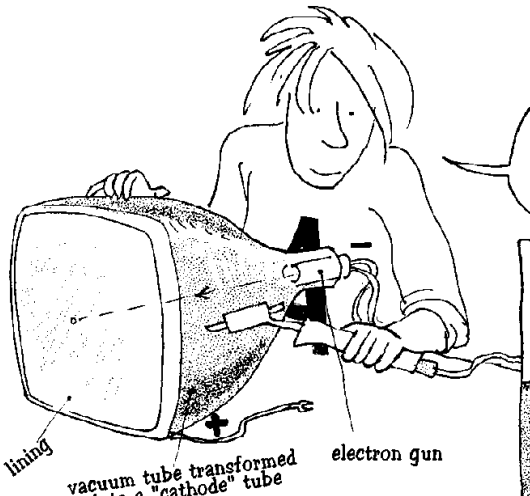
With an electron gun I can canalise electrons emitted by a filament. Then cold cathodes can allow me to deflect a fine paintbrush line of electrons at will.

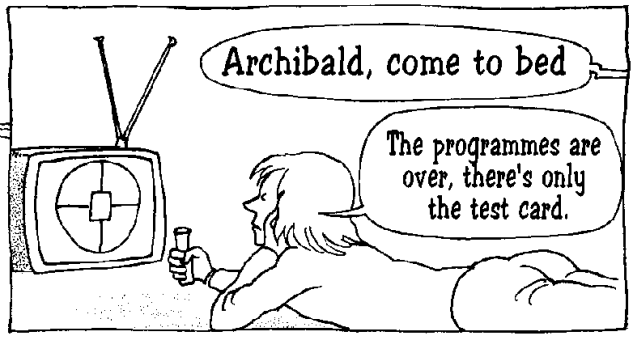


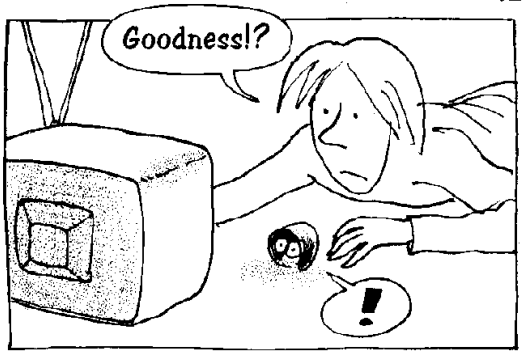
With two sets of electrodes we have complete and precise control of the brush



This television is the right sort of modification of a vacuum bell's geometry.

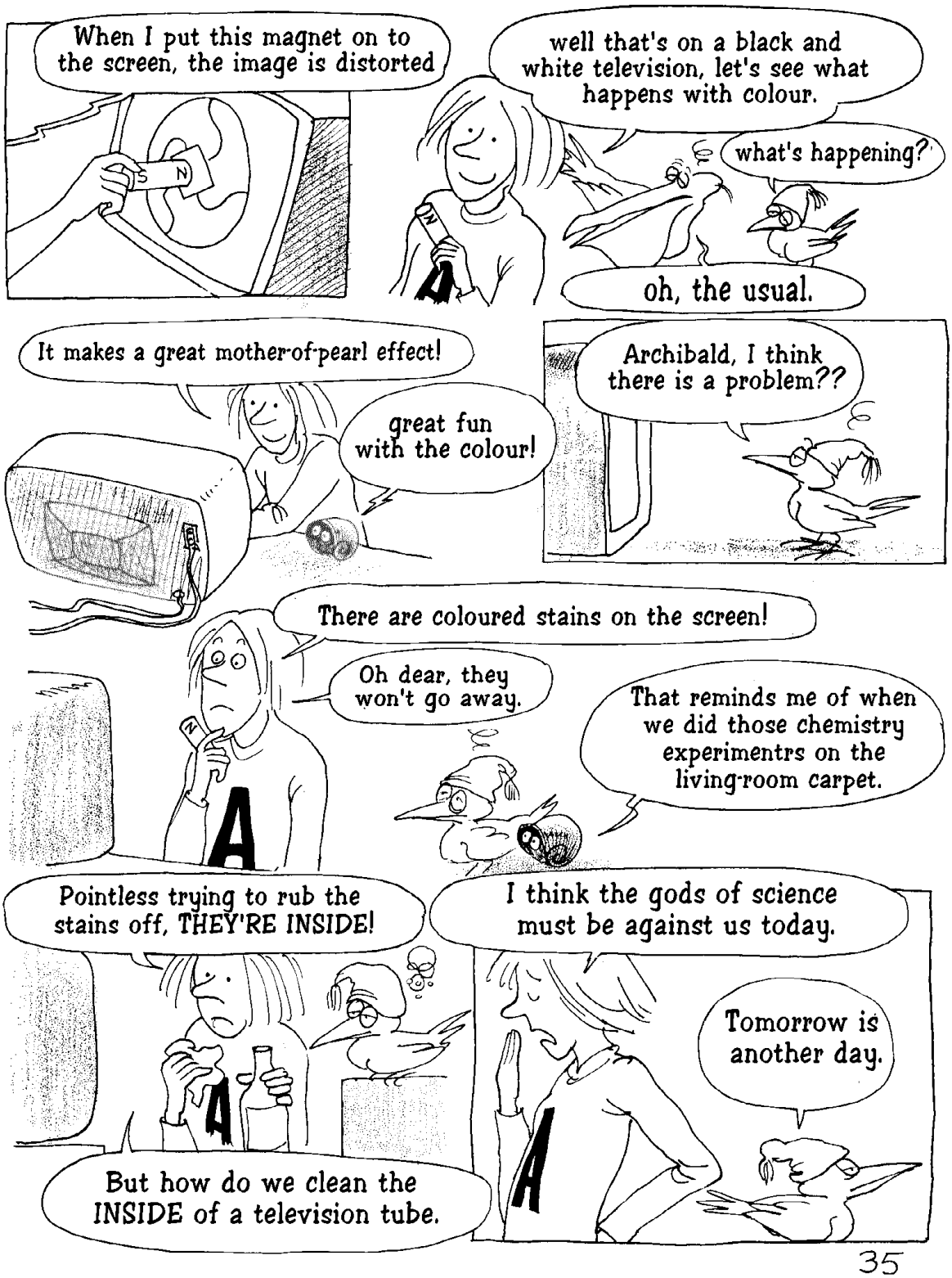




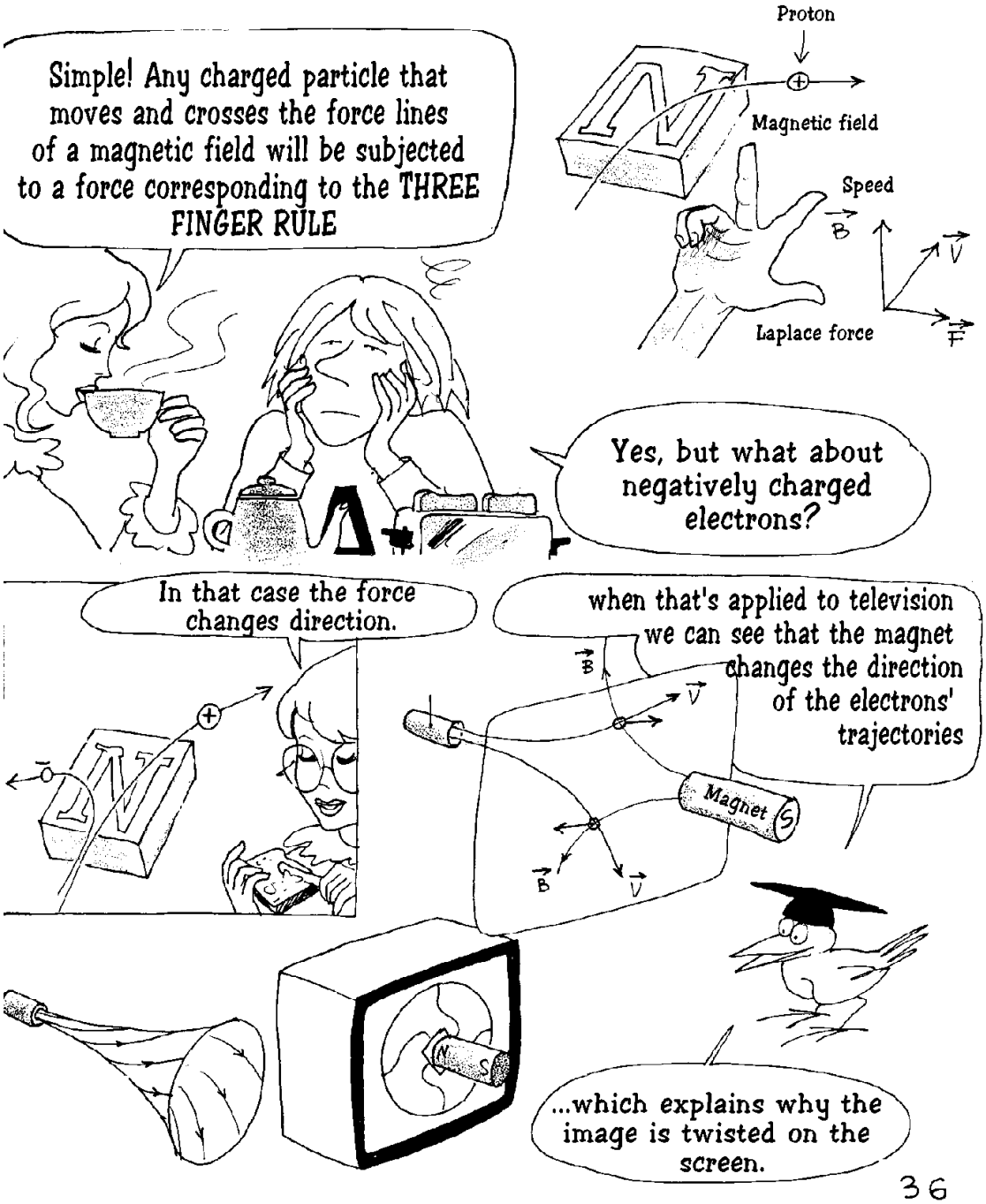


Sophie, you must come and see, it's great!..

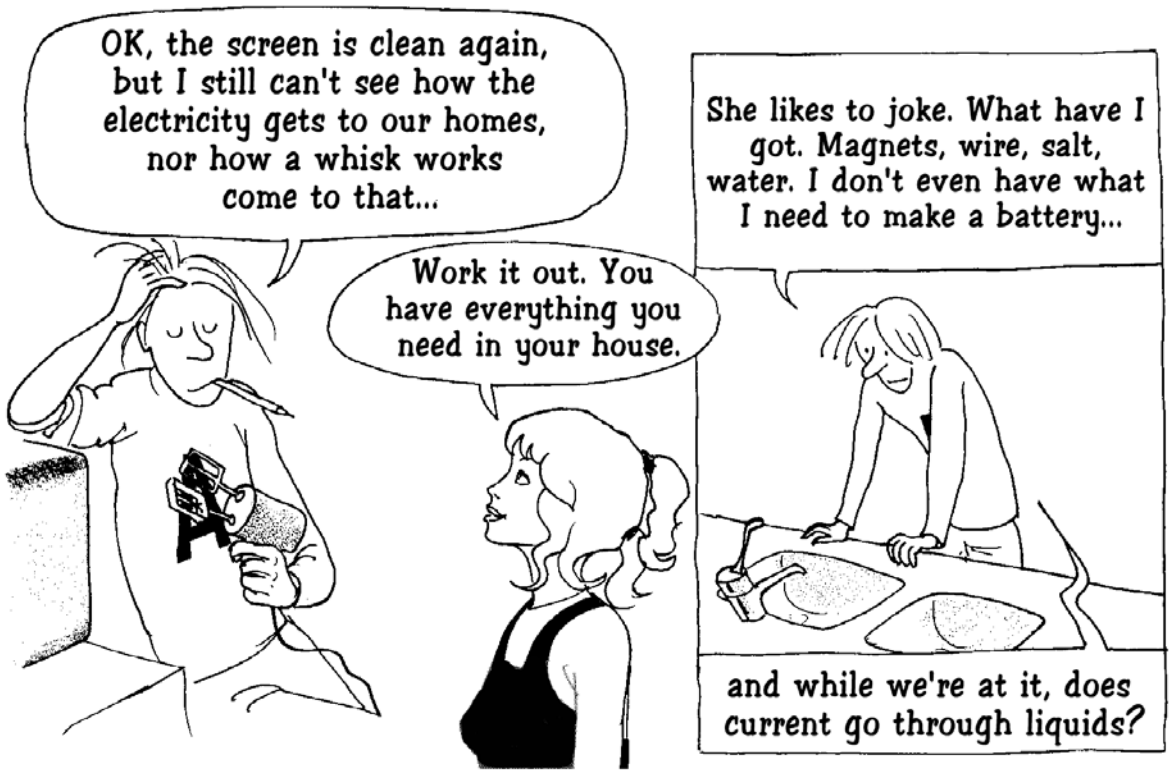
Tomorrow...I'm asleep


When I put this magnet on to the screen, the image is distorted
S
N
well that's on a black and white television, let's see what happens with colour.
what's happening?
oh, the usual.
It makes a great mother-of-pearl effect!
great fun with the colour!
Archibald, I think there is a problem??
There are coloured stains on the screen!
Oh dear, they won't go away.
That reminds me of when we did those chemistry experimentrs on the living-room carpet.
Pointless trying to rub the stains off, THEY'RE INSIDE!
I think the gods of science must be against us today.
Tomorrow is another day.
But how do we clean the INSIDE of a television tube.

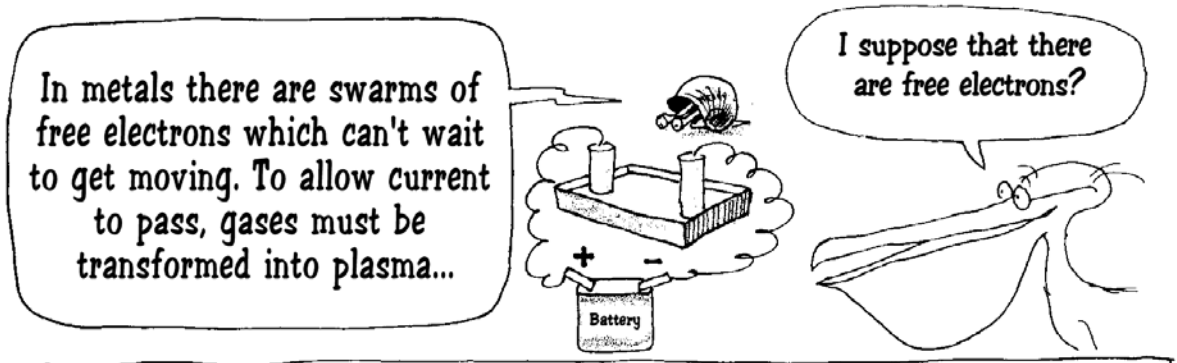
THE LAPLACE FORCE



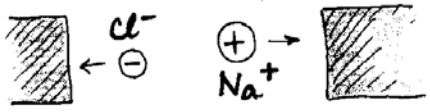
(*) by combining them we can get all the colours of the rainbow.



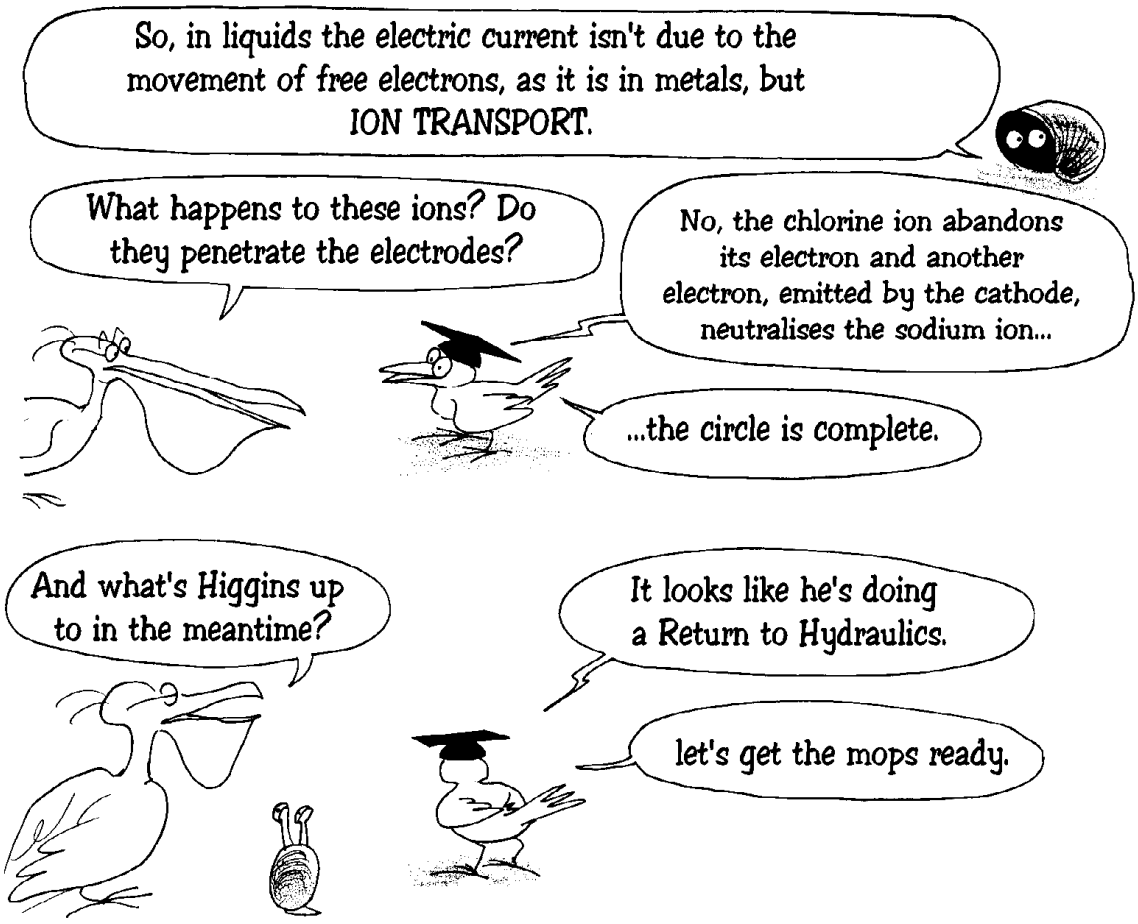
ELECTROLITES



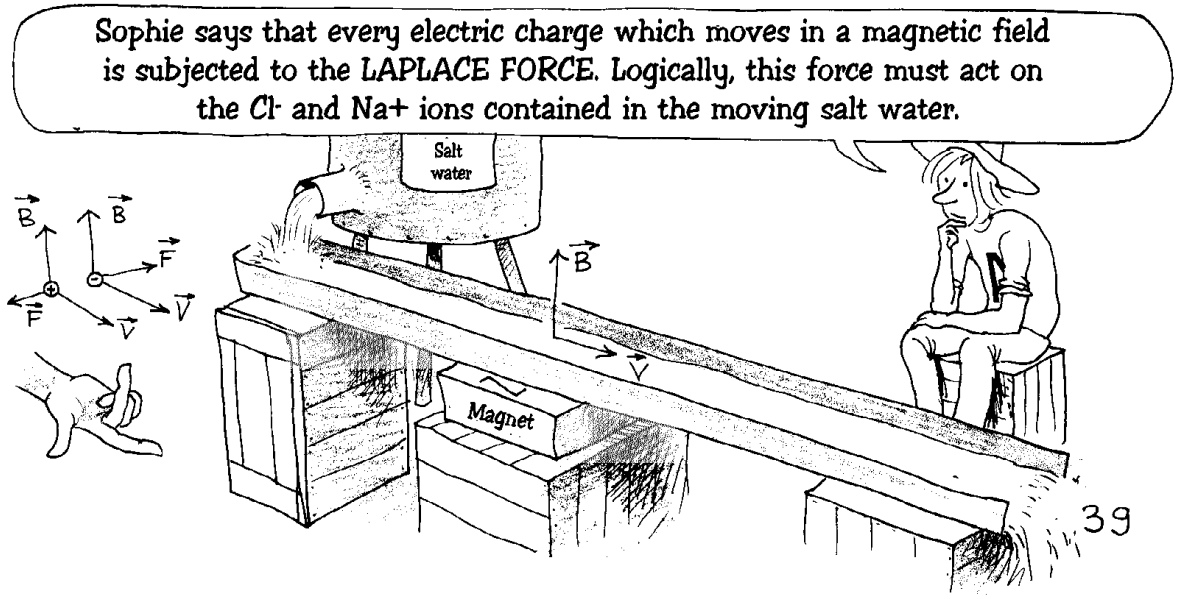
When domestic salt, sodium chloride, ClNa, is dissolved in water its atoms are dispersed in the liquid the chlorine takes over a sodium electron. This Chlorine ION Cl- moves towards the anode while the NA+ ion moves towards the cathode.

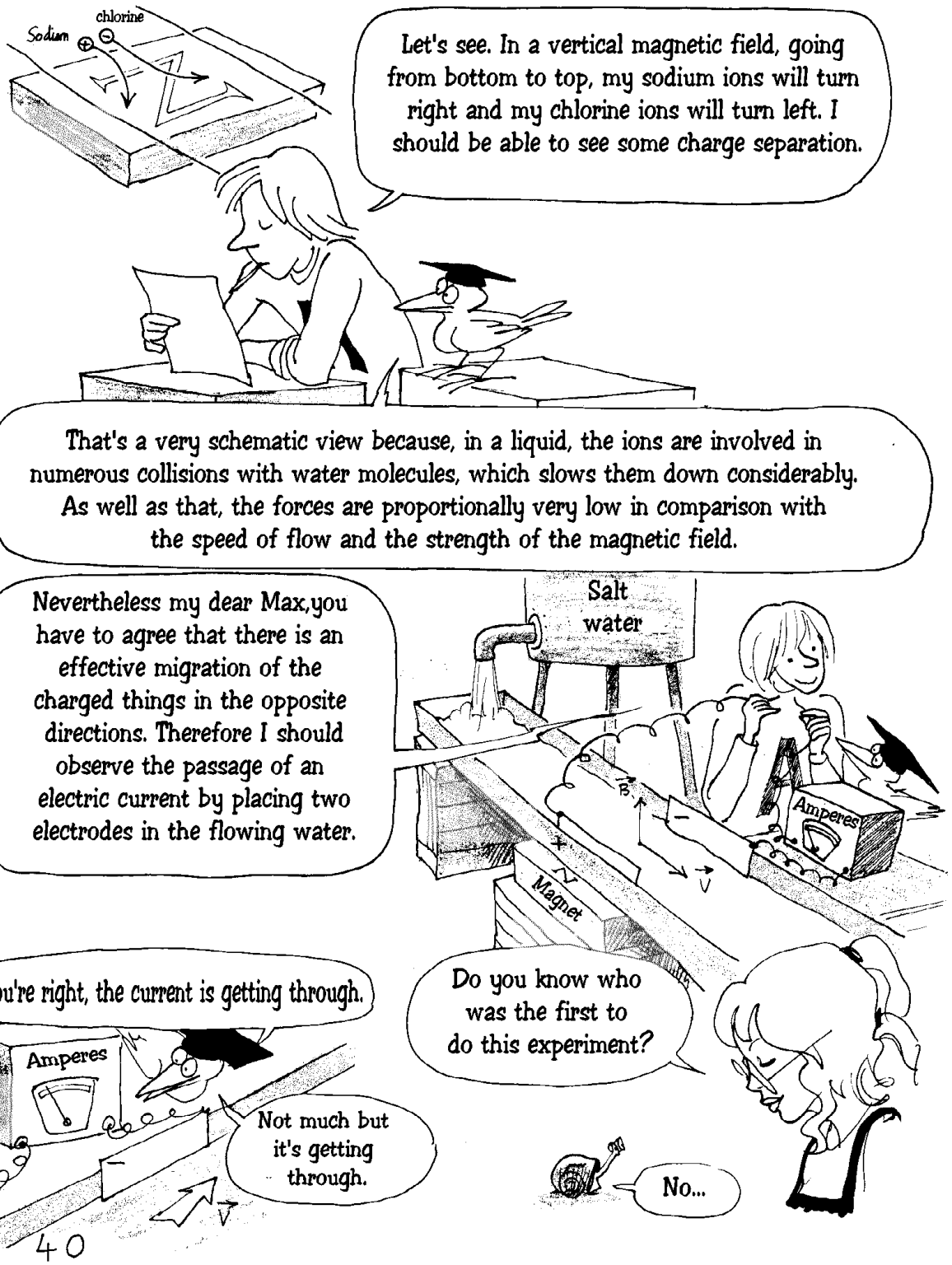


The Management.



ELECTROMOTIVE FORCE




Sodium
chlorine
Let's see. In a vertical magnetic field, going from bottom to top, my sodium ions will turn right and my chlorine ions will turn left. I should be able to see some charge separation.
That's a very schematic view because, in a liquid, the ions are involved in numerous collisions with water molecules, which slows them down considerably. As well as that, the forces are proportionally very low in comparison with the speed of flow and the strength of the magnetic field.
Nevertheless my dear Max,you have to agree that there is an effective migration of the charged things in the opposite directions. Therefore I should observe the passage of an electric current by placing two electrodes in the flowing water.
Salt water
Amperes
Magnet
Do you know who was the first to do this experiment?
No...
You're right, the current is getting through.
Amperes
Not much but it's getting through.
40

BARLOW'S WHEEL

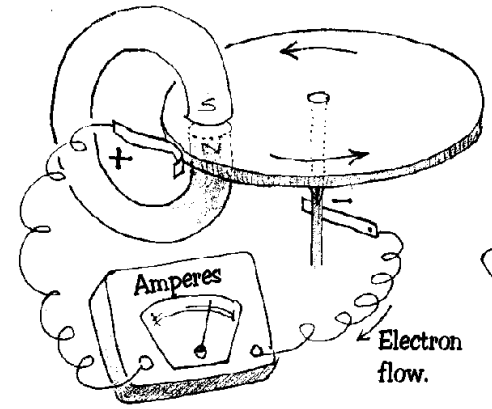
The Englishman Michael Faraday in 1857. He used the salty water of the Thames when the tide rose and fell ...and the vertical component of the Earth's magnetic field: barely a tenth of a Gauss (*). He thus invented the type of electric generator called MAGNETOHYDRODYNAMIC, or MHD for short.

But such a generator has a ridiculously low power.

Maybe water isn't the best ingredient for making an electric generator.

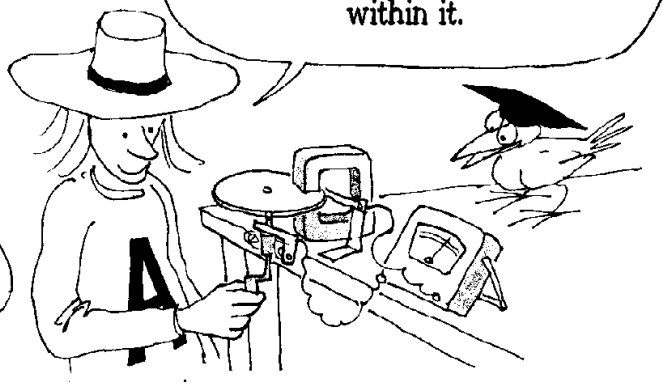
So what should we use? Copper in fusion?

Why just stick with a liquid?



So here is our first ELECTRIC GENERATOR

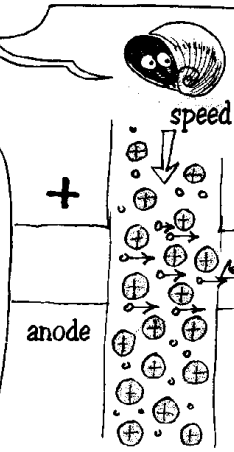
Sophie's right. If we turn a metal disk in the airgap of a magnet it brings about a migration of electric charges, electrons in this case, because the positive charges in the metal can't move within it.



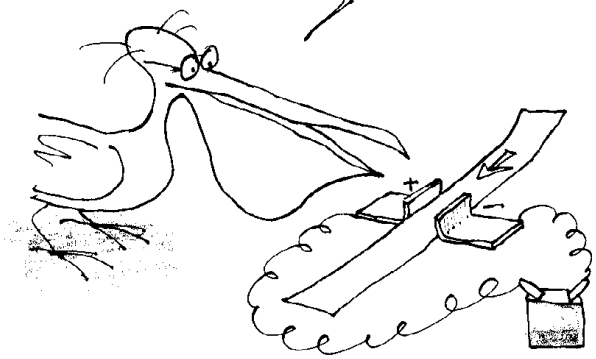
* The smallest magnet of a seamstress is about a hundred Gauss.


When I move the conductor in the airgap of a magnet I can feel a certain force resisting.
You see the charges are like vehicles going along a highway, represented by the movement of the metal. The positive charges are heavy lorries, incapables of turning right or left or changing speed. Their movement depends on the flow of all the other vehicles,each linked to the others. The electrons are like tiny motorbike riders who, at the beginning, also follow the flow.
Eh! Did you see how he cut me up!?!
No manners these electrons.
They make me have to slow down.
And I've got other things to do!!
And suddenly, this is what happens.
Another one getting annoyed for nothing!
METAL NUCLEUS
Electrons Follow the diversion
Get out of the way idiot!
!!!

This is the explanation, on a microscopic level, of why a force needs to be exerted, to furnish WORK in order to produce electric energy.

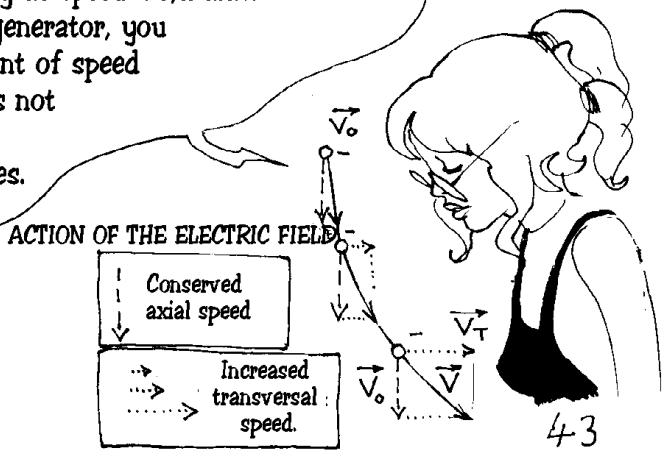


Remove a last doubt. Forget the magnetic field. Couldn't I obtain an equivalent braking force by provoking the lateral diversion of the electron flow towards the electrodes but, this time, in an electric field created by a generator?

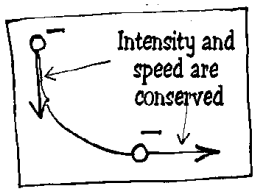


No Leon, that would be completely different.

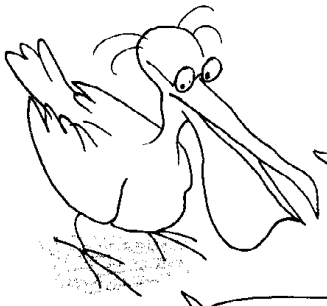
When you act on an electric charge, buried in the heart of an atom flow and moving at speed $\vec{V}o$, thanks to an electric force created by a generator, you are adding a transversal component of speed $\vec{V}t$. But the axial component $\vec{V}o$ is not modified. Therefore a generator transfers energy to electric charges.



ACTION OF THE MAGNETIC FIELD



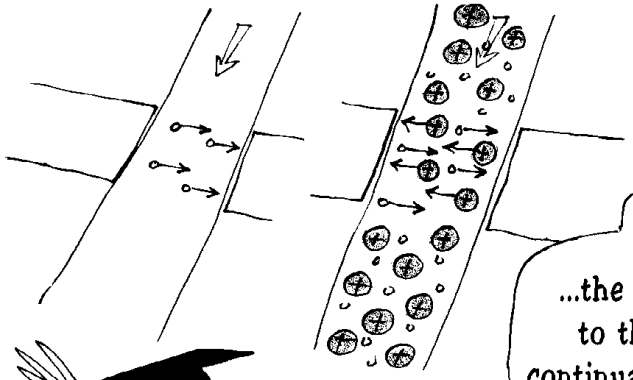
However a transversal magnetic field does not modify the kinetic energy ½mV of the charged particle. The direction of the speed changes but not its intensity. So the axial component of this speed, parallel to the general flow, diminishes and so a braking of the conductor results.

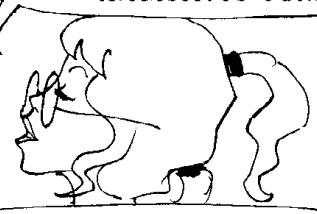


Yes but in both cases, I'm transversally calling on my population of free electrons...

...so I should observe a transversal force.

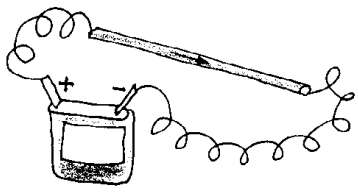
Leon, you're forgetting that the LAPLACE FORCE is acting on the positive charges and that the forces balance themselves out...





...the electric charges, strongly attached to the conductor transmit this force continually, so the free charges periodically retransmit this force through collisions.

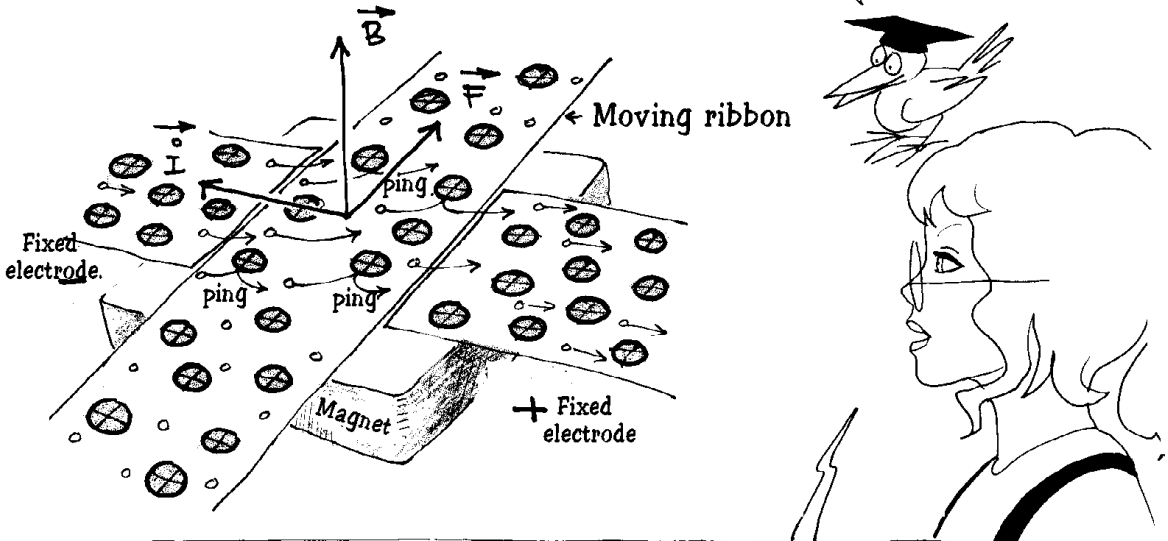
That's why when electricity flows in the wire, it doesn't pull it.



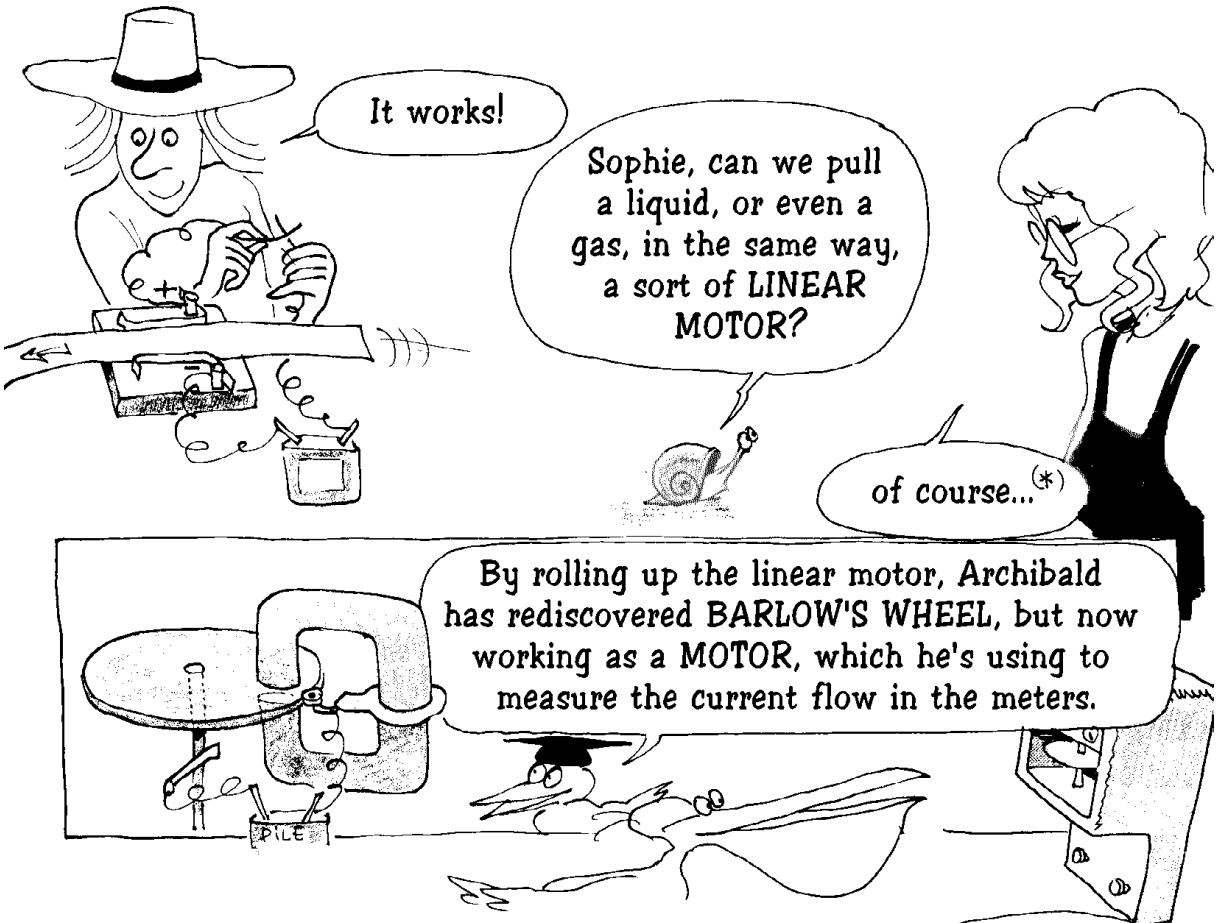
THE ELECTRIC MOTOR

That's given me an idea. By sending a current transversally through the ribbon conductor I am not creating a force. OK, that's been shown, but what happens if I combine the two effects: current flowing from the generator and the rotation of the speed vector because of the effect of a magnetic field perpendicular to the speed of the charges?

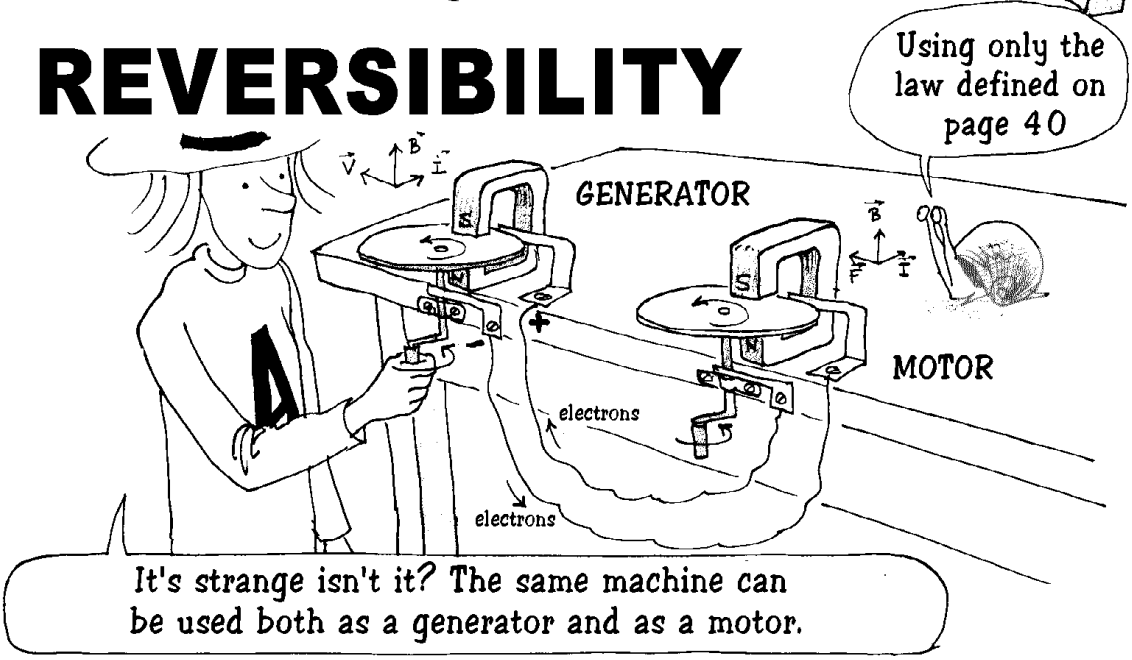
The generator will start to move electrons which will tend to cross the ribbon, passing from the cathode to the anode. But the magnetic field, by curving their trajectory inwards, will transmit part of the acquired impulsion along the axis of the ribbon, which will thus be subjected to a force.



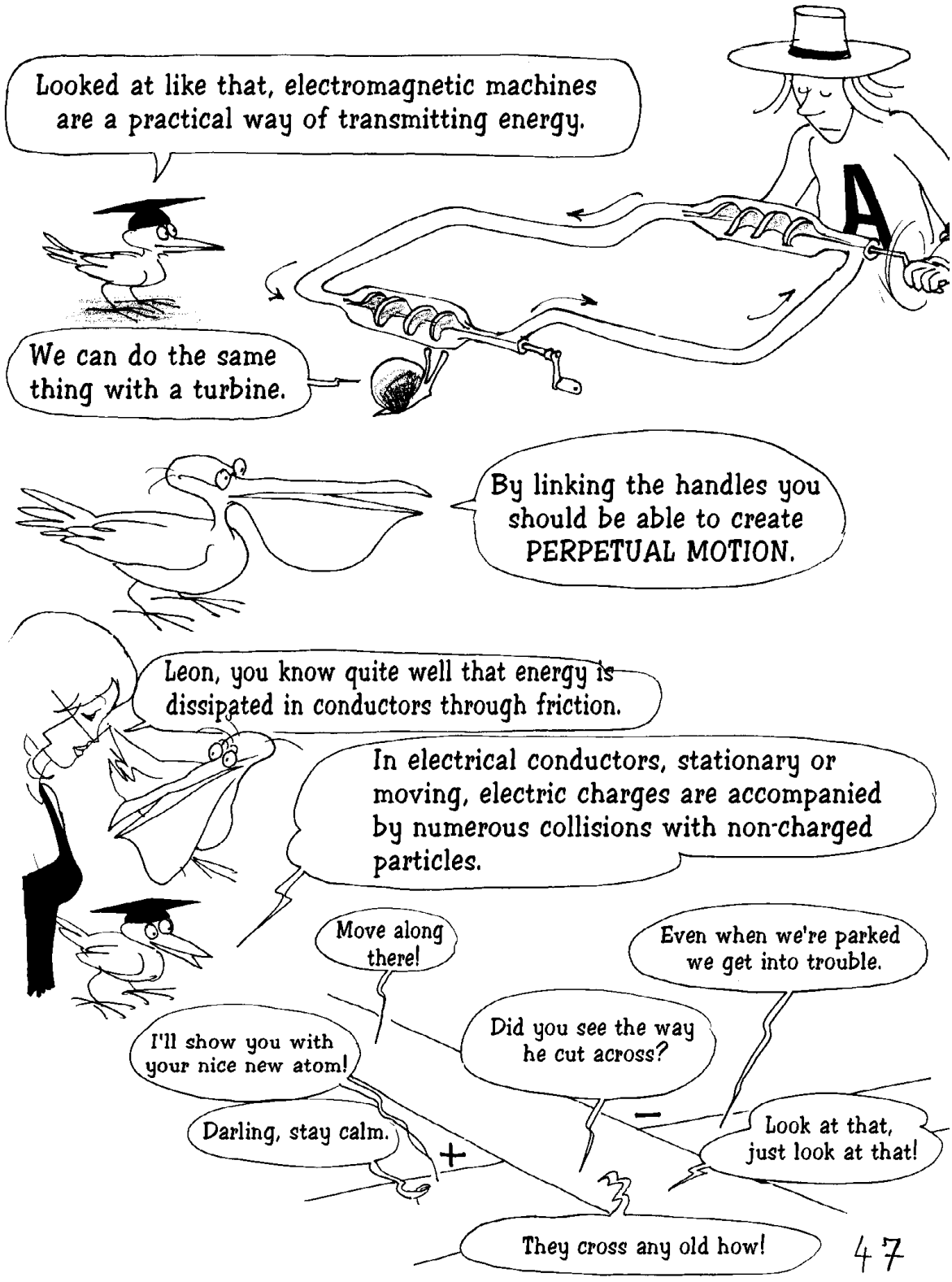
An analysis of microscopic behaviour, at atomic scale, allows us to work out the macroscopic behaviour, at the level of our experiment.



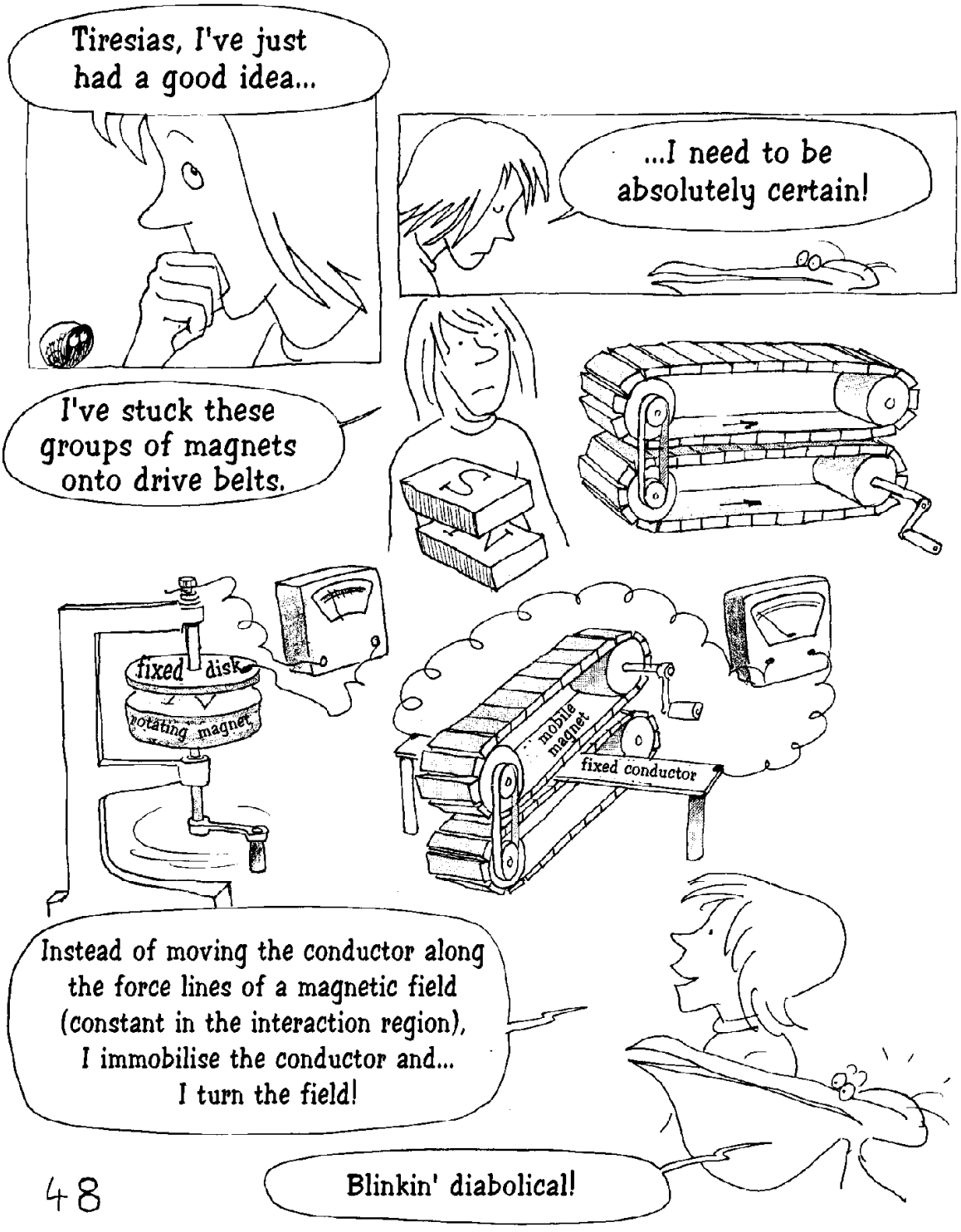
REVERSIBILITY

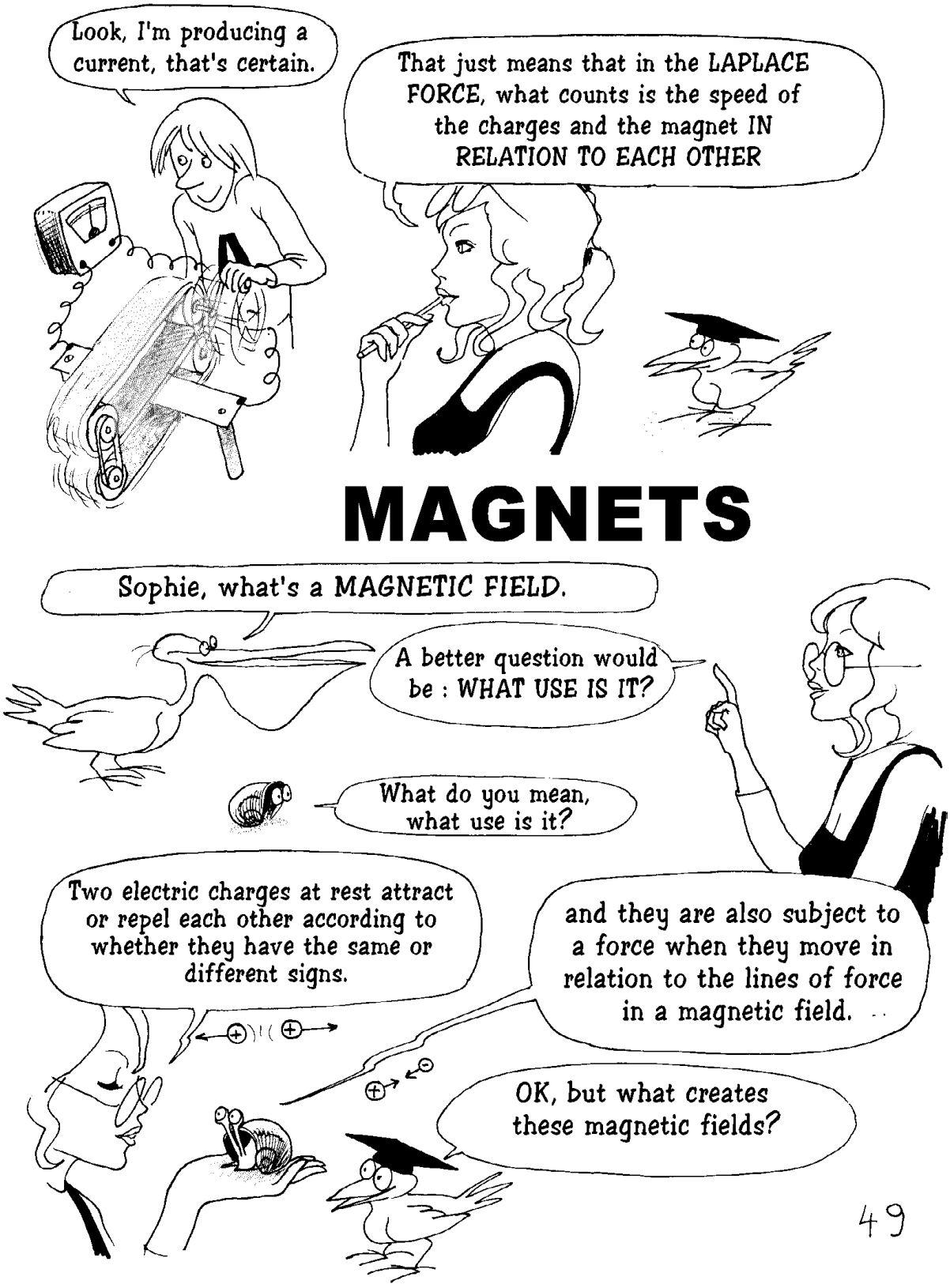


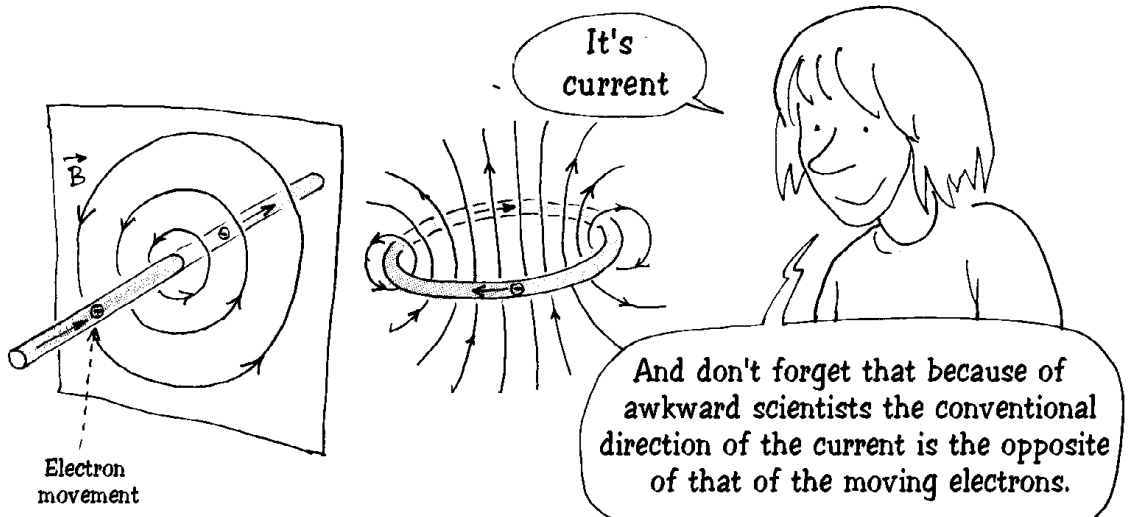
(*) See THE SILENCE BARRIER

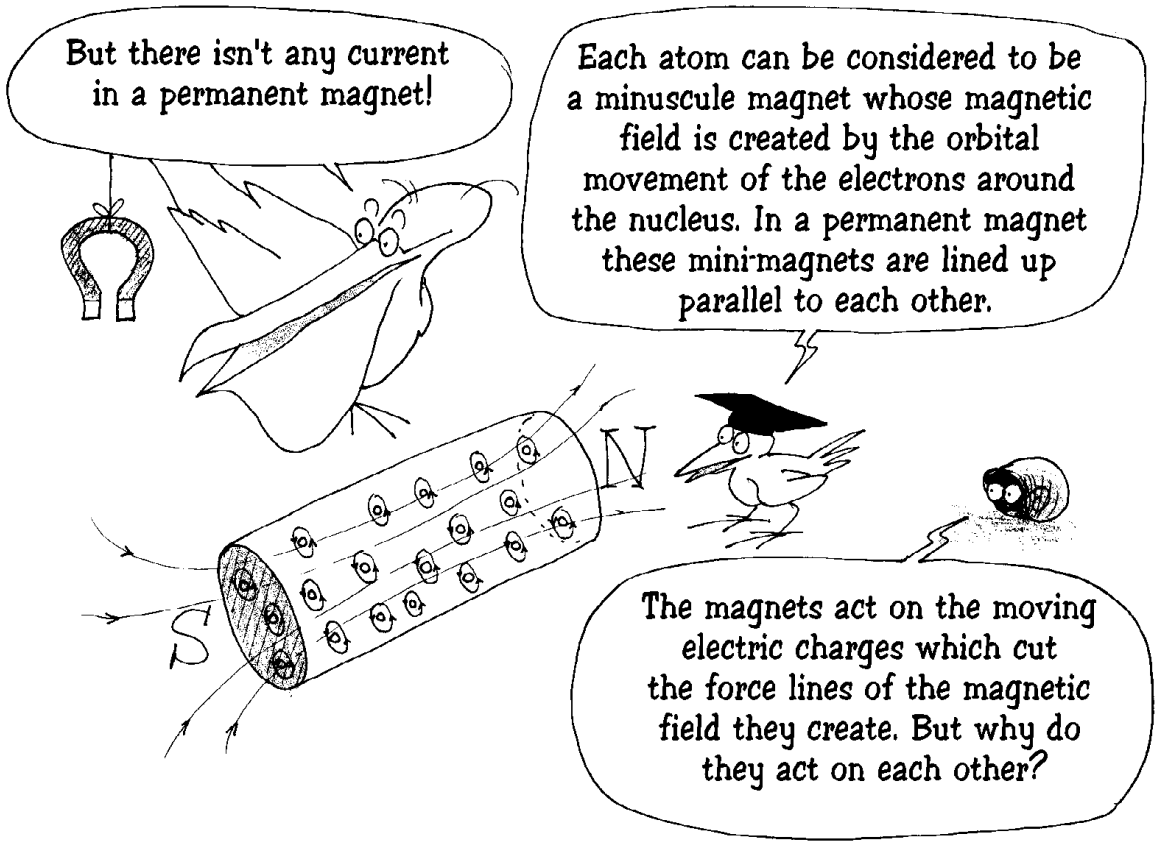

Looked at like that, electromagnetic machines are a practical way of transmitting energy.
A
We can do the same thing with a turbine.
By linking the handles you should be able to create PERPETUAL MOTION.
Leon, you know quite well that energy is dissipated in conductors through friction.
In electrical conductors, stationary or moving, electric charges are accompanied by numerous collisions with non-charged particles.
Move along there!
Even when we're parked we get into trouble.
I'll show you with your nice new atom!
Did you see the way he cut across?
Darling, stay calm.
+
−
Look at that, just look at that!
They cross any old how!

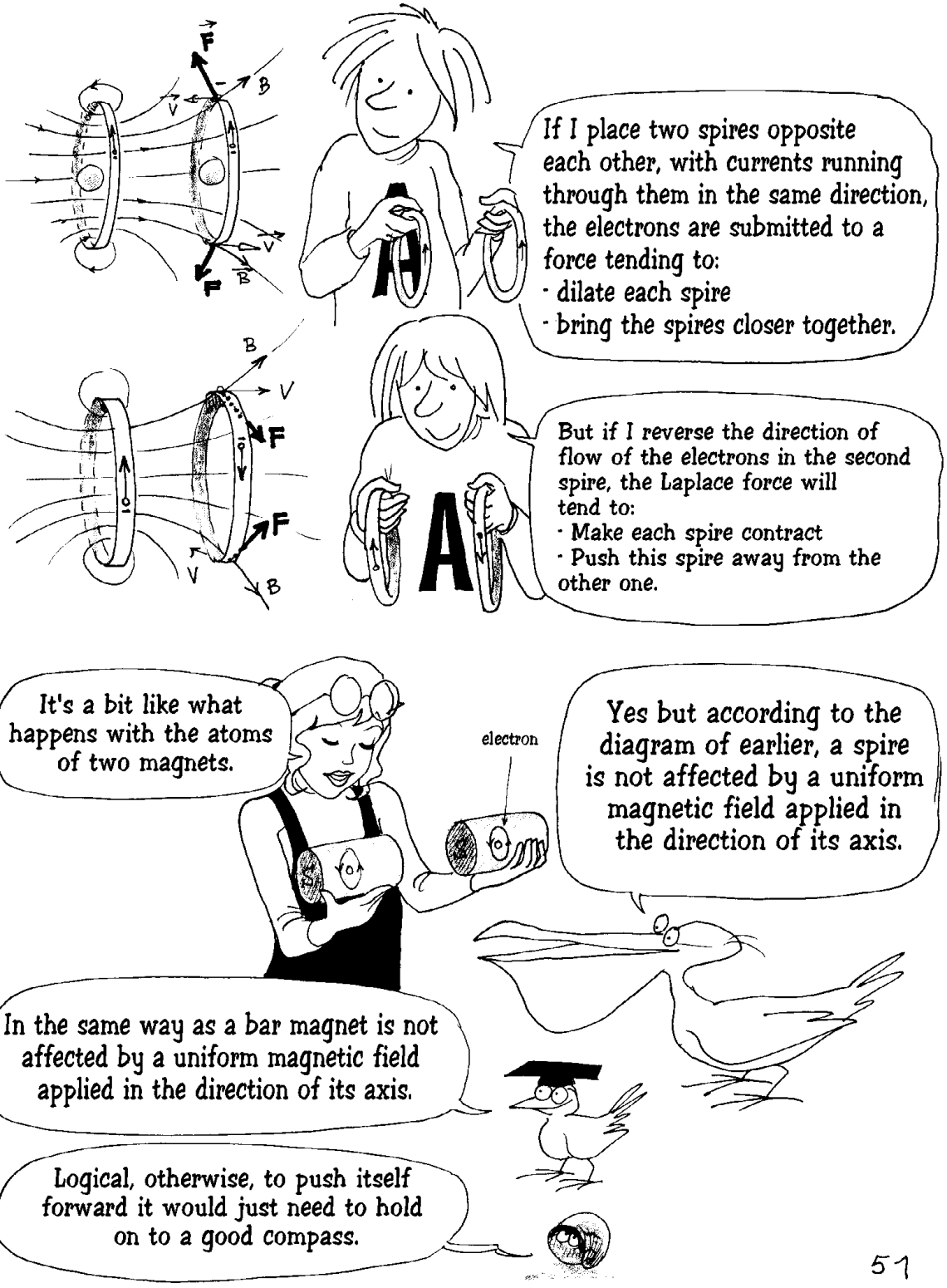
RELATiViTY


Tiresias, I've just had a good idea...
...I need to be absolutely certain!
I've stuck these groups of magnets onto drive belts.
S
fixed disk
rotating magnet
mobile magnet
fixed conductor
Instead of moving the conductor along the force lines of a magnetic field (constant in the interaction region), I immobilise the conductor and... I turn the field!
Blinkin' diabolical!

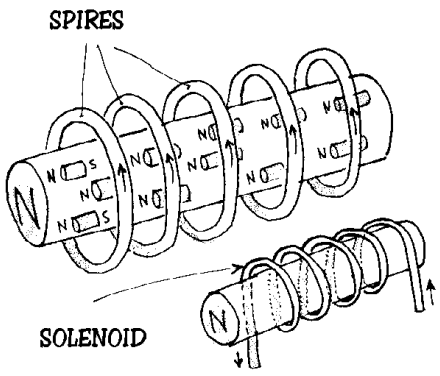

Look, I'm producing a current, that's certain.
That just means that in the LAPLACE FORCE, what counts is the speed of the charges and the magnet IN RELATION TO EACH OTHER
MAGNETS
Sophie, what's a MAGNETIC FIELD.
A better question would be : WHAT USE IS IT?
What do you mean, what use is it?
Two electric charges at rest attract or repel each other according to whether they have the same or different signs.
and they are also subject to a force when they move in relation to the lines of force in a magnetic field.
OK, but what creates these magnetic fields?


It's current
B
Electron movement
And don't forget that because of awkward scientists the conventional direction of the current is the opposite of that of the moving electrons.

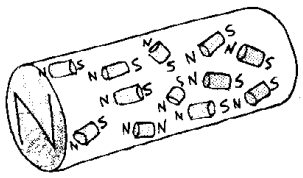

But there isn't any current in a permanent magnet!
Each atom can be considered to be a minuscule magnet whose magnetic field is created by the orbital movement of the electrons around the nucleus. In a permanent magnet these mini-magnets are lined up parallel to each other.
N
S
The magnets act on the moving electric charges which cut the force lines of the magnetic field they create. But why do they act on each other?


If I place two spires opposite each other, with currents running through them in the same direction, the electrons are submitted to a force tending to:
- dilate each spire
- bring the spires closer together.
But if I reverse the direction of flow of the electrons in the second spire, the Laplace force will tend to:
- Make each spire contract
- Push this spire away from the other one.
It's a bit like what happens with the atoms of two magnets.
electron
Yes but according to the diagram of earlier, a spire is not affected by a uniform magnetic field applied in the direction of its axis.
In the same way as a bar magnet is not affected by a uniform magnetic field applied in the direction of its axis.
Logical, otherwise, to push itself forward it would just need to hold on to a good compass.

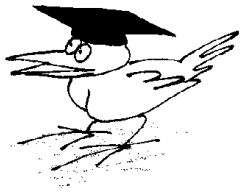

However a spire placed in a magnetic field tends to turn in such a way that its own field will line up with the first. This is the basis of the MOBILE FRAME GALVANOMETER. In fact a compass is nothing more than a collection of galvanometers of the same type.
Pile
So, can someone explain to me why a magnet attracts iron but not lead, or sugar?
It's simple: iron atoms are also little magnets. They also have a certain mobility. When approached by a sufficiently powerful magnet the iron atoms turn and align, and the iron itself also becomes a magnet whose field is superimposed on that of the inductor magnet.
Nothing with sugar
OK...
Atom "magnets" (varying orientation)
Oriented atom "magnets"
N MAGNET
the piece of iron has become a magnet



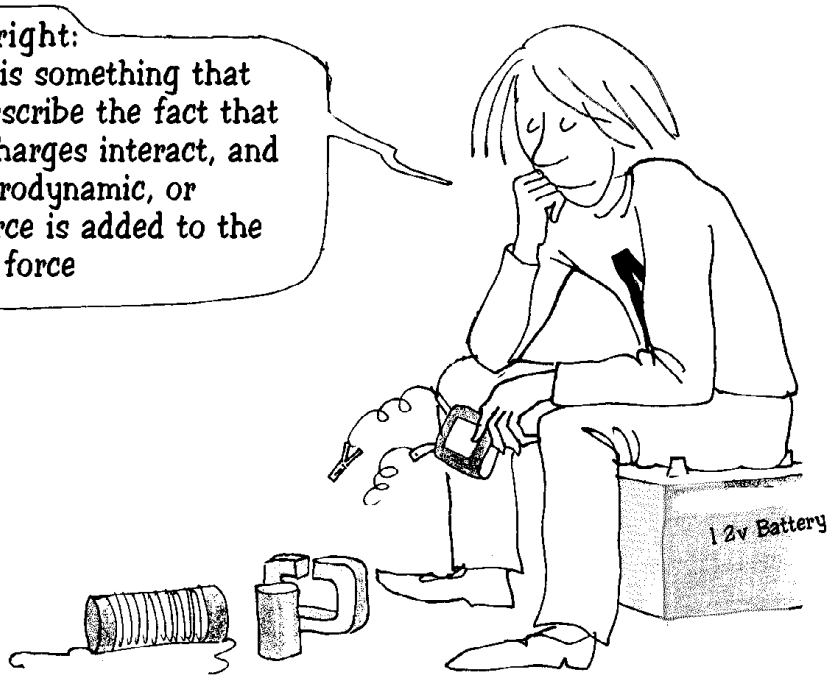
I understand now why we put an IRON CORE in ELECTROMAGNETS. It reinforces the fields created in the system by the spires.



When we take away the magnetising magnet or the solenoid, the iron's atom-magnets will retain, up to a point, their orientation. A RESIDUAL MAGNETISM will subsist...

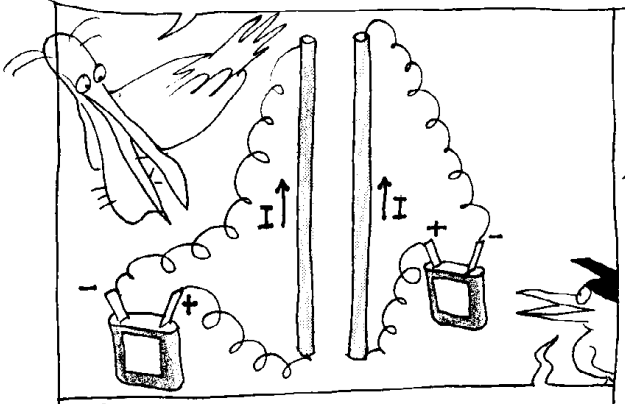


So if I've got it right:
the magnetic field is something that was invented to describe the fact that MOVING electric charges interact, and that this new electrodynamic, or electromagnetic force is added to the basic, electrostatic force



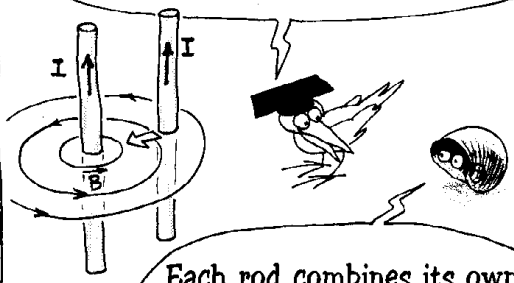
RELATIVITY AGAIN

How can we measure a magnetic field as objectively as possible?

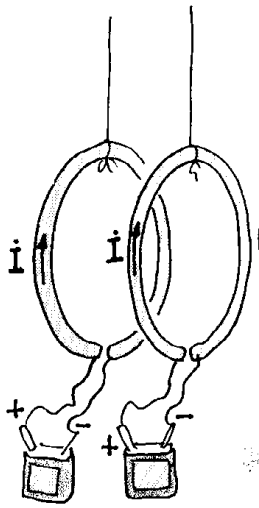


Well we can put deux rods parallels to each other and with an electric current of intensity I flowing through them

Under these conditions the two rods will be subject to a mutually equal force of attraction.

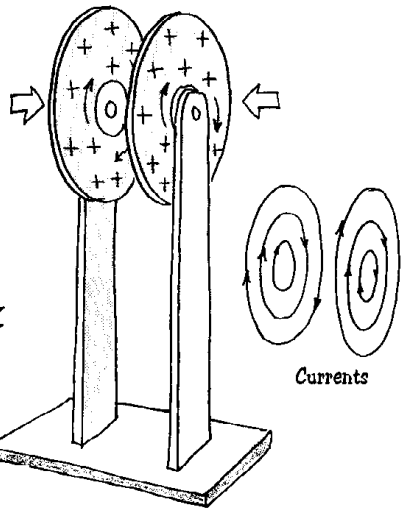


Each rod combines its own current with the magnetic field created by the other rod.



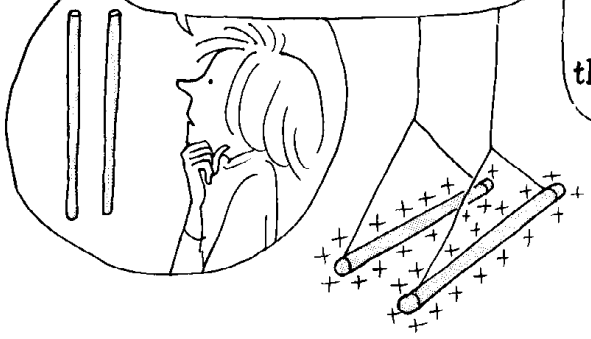
We could roll the rods so that they made two spires which, as they have parallel currents running through them, would move towards each other

As we saw already on page 51

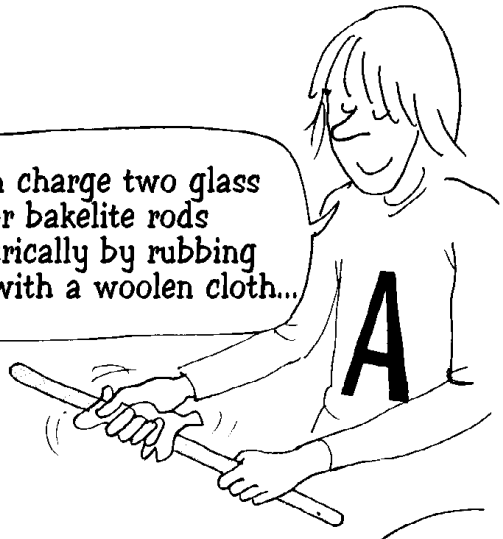


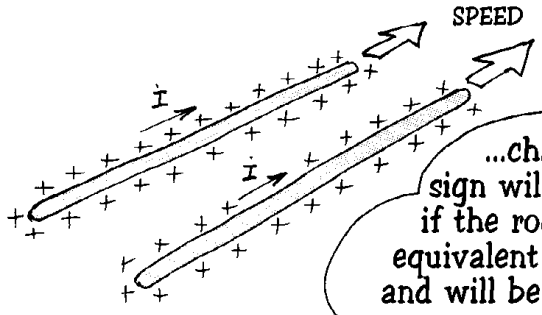
In the same way we can send electric currents with the same sign through disks facing each other and so make them turn. This is equivalent to current and is accompanied by an electromagnetic force.

Just look at that...



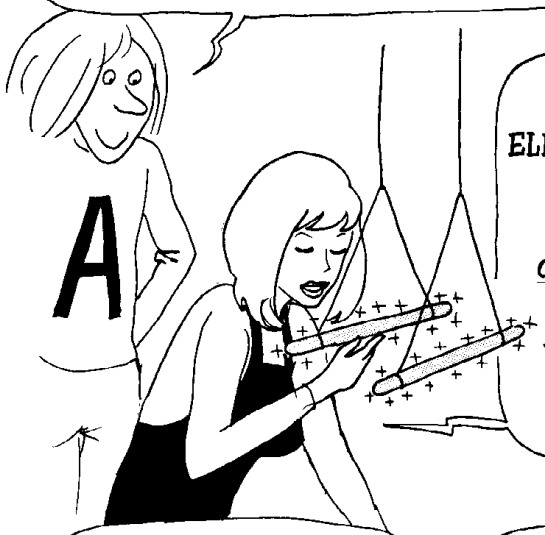
I can charge two glass or bakelite rods electrically by rubbing them with a woolen cloth...





...charges of the same sign will repel each other but if the rods move like this, it is equivalent to two parallel currents and will be accompanied by a slight attractive component.

The earth moves around the sun which itself orbits in our galaxy, the Milky Way, at 234 km/h. The galaxy may also be moving in relation to the universe. It's amazing Sophie: By pointing these two parallel, electrically charged rods to the sky in any direction and in measuring the force acting between them, we should be able to work out the direction of our movement in the Universe and our speed!



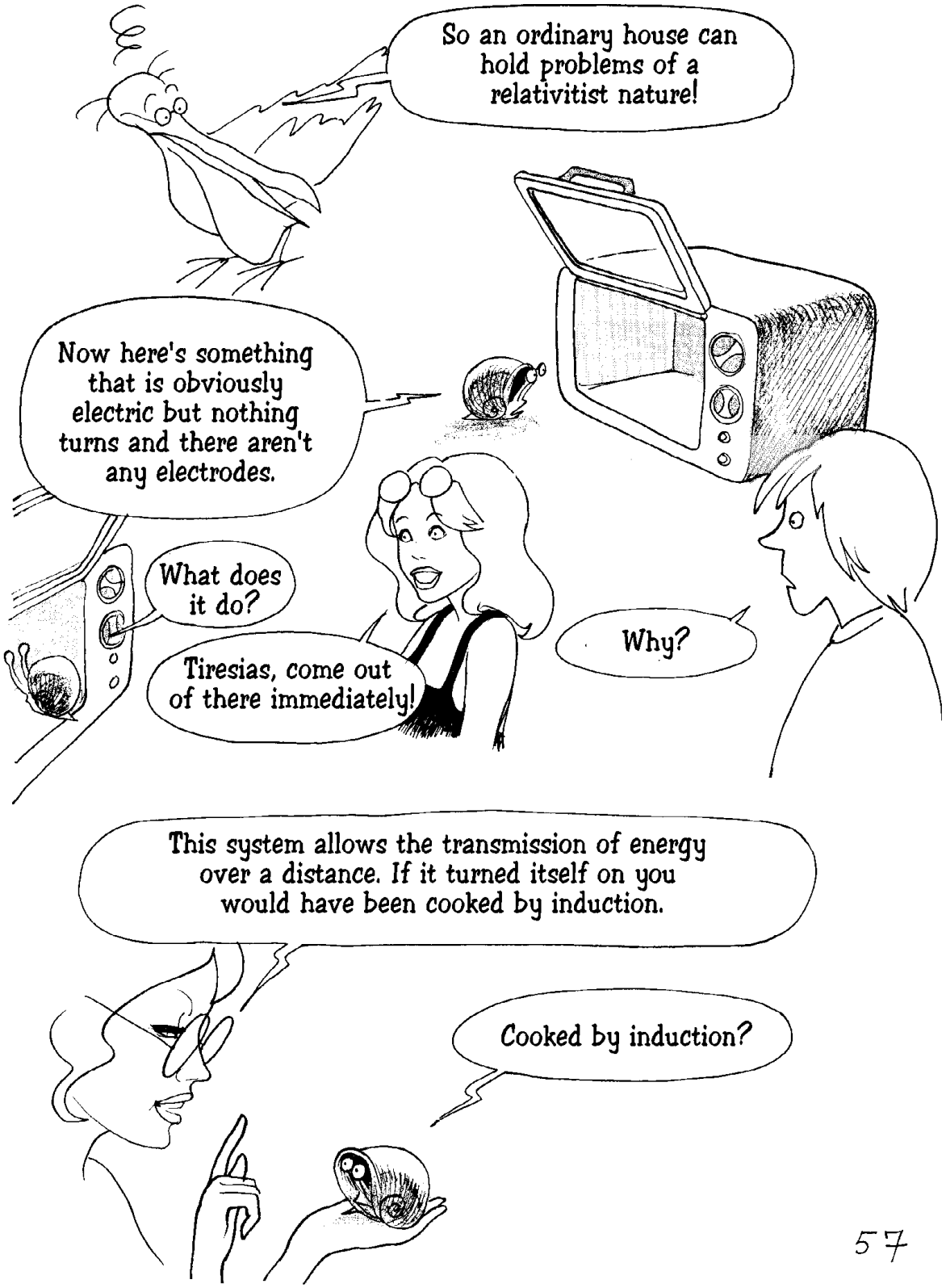
No, you won't measure anything. This ELECTROMAGNETIC FORCE, associated with MOVEMENT, is only perceptible by an observer who moves in relation to the charges. But whatever our movement, in relation to the sun, to the galaxy or the cosmos, we are moving at the same speed as the rods.

Electromagnetism is essentially relativist.

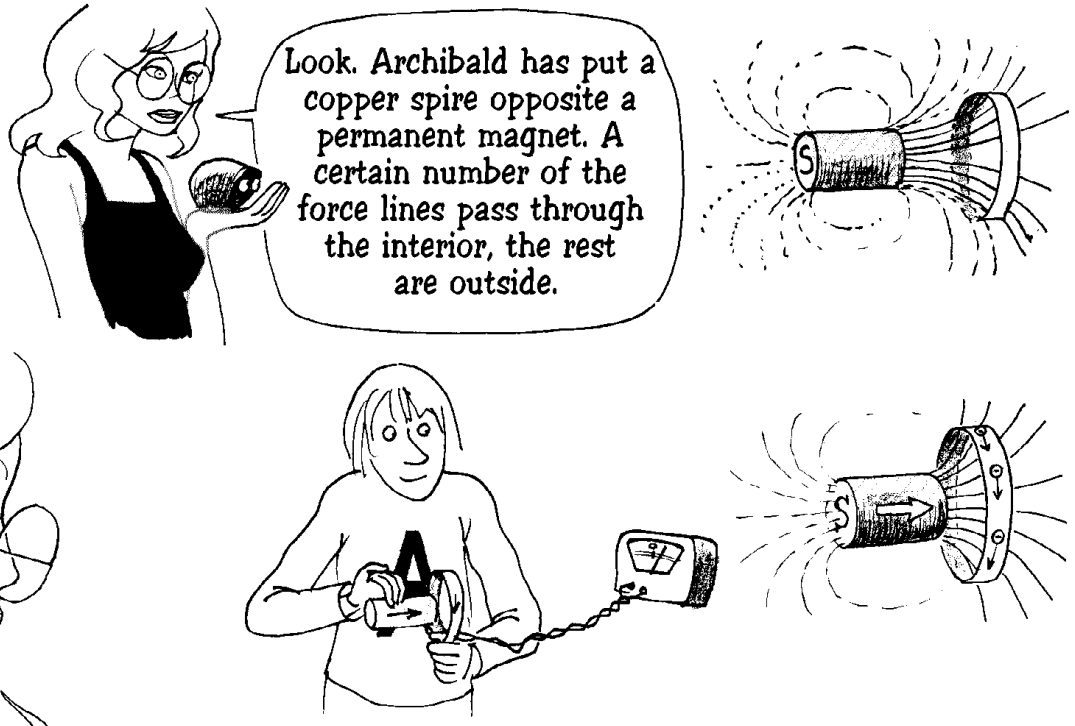
It's true that the experiment Achibald suggested recalls that of MICHELSON (*) at the beginning of the twentieth century. It consisted of measuring the speed of light in all directions in order to discover the absolute direction of the earth in the Universe.

I can't say I'm surprised because I was told that light was an electromagnetic wave.

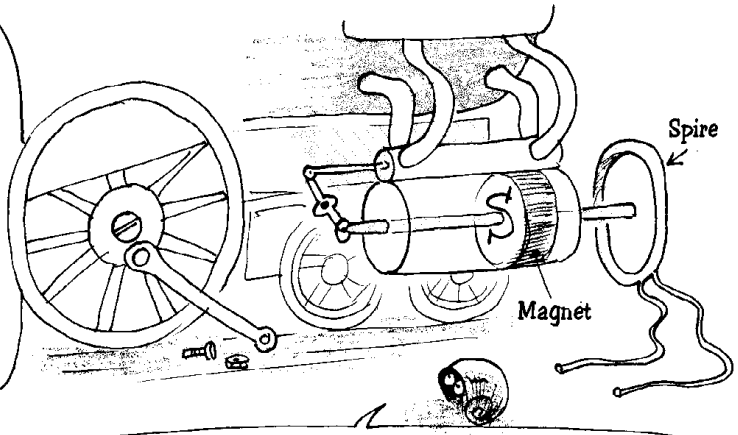
(*) Michelson, Physician. Nobel prize 1907


So an ordinary house can hold problems of a relativitist nature!
Now here's something that is obviously electric but nothing turns and there aren't any electrodes.
What does it do?
Tiresias, come out of there immediately!
Why?
This system allows the transmission of energy over a distance. If it turned itself on you would have been cooked by induction.
Cooked by induction?

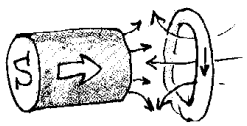
INDUCTION


Look. Archibald has put a copper spire opposite a permanent magnet. A certain number of the force lines pass through the interior, the rest are outside.
S
S
Now he's bringing the magnet closer to the spire, in other words he is moving the group of force lines as a block. As they cross the metal of the spire an electromagnetic force results which, acting on electrons, is an INDUCED current.
If the magnet and the spire are static in relation to each other, the current cancels itself out.
But if you pull the magnet, the current is reversed.
magnetic field
FORCE ACTING ON THE PROTON
Speed
FORCE ACTING ON THE ELECTRON
Yet one more application of LAPLACE's law.

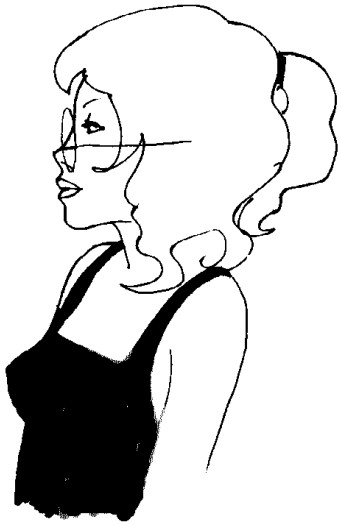
Look Tiresias, I've modified this steam engine by replacing the piston with a magnet, so you can make to-and-fro movements and create an ALTERNATING CURRENT in the spire.

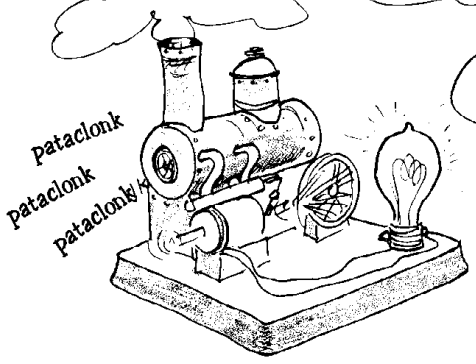


If the piston slides without friction we will have found a way to produce free electric energy, if we ignore, of course, a small loss through the Joule effect in the spire.

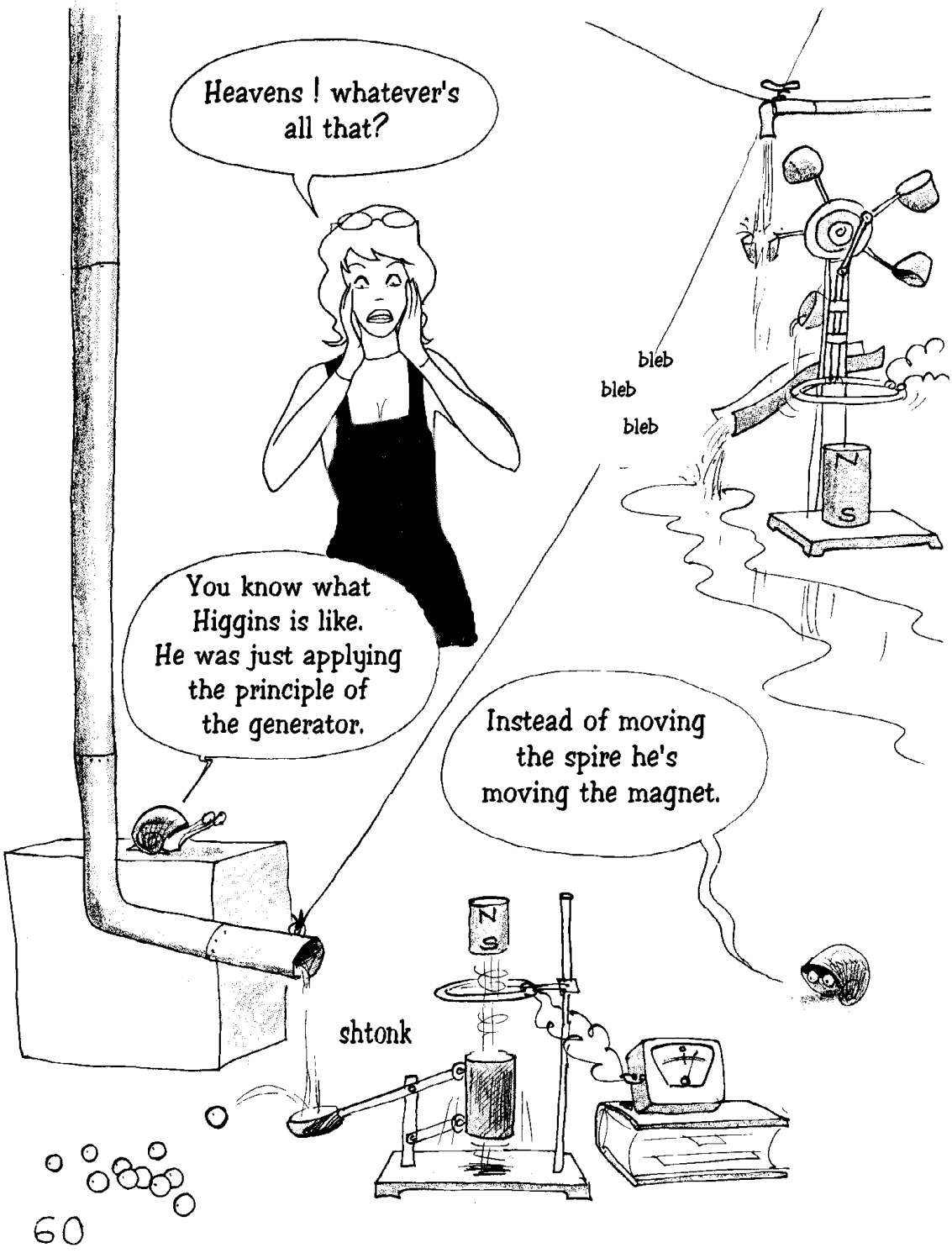


You're forgetting that the passage of current will create its own magnetic field which will oppose the movement of the magnet-piston (LENZ'S LAW). So WORK will have to be applied to produce this energy.

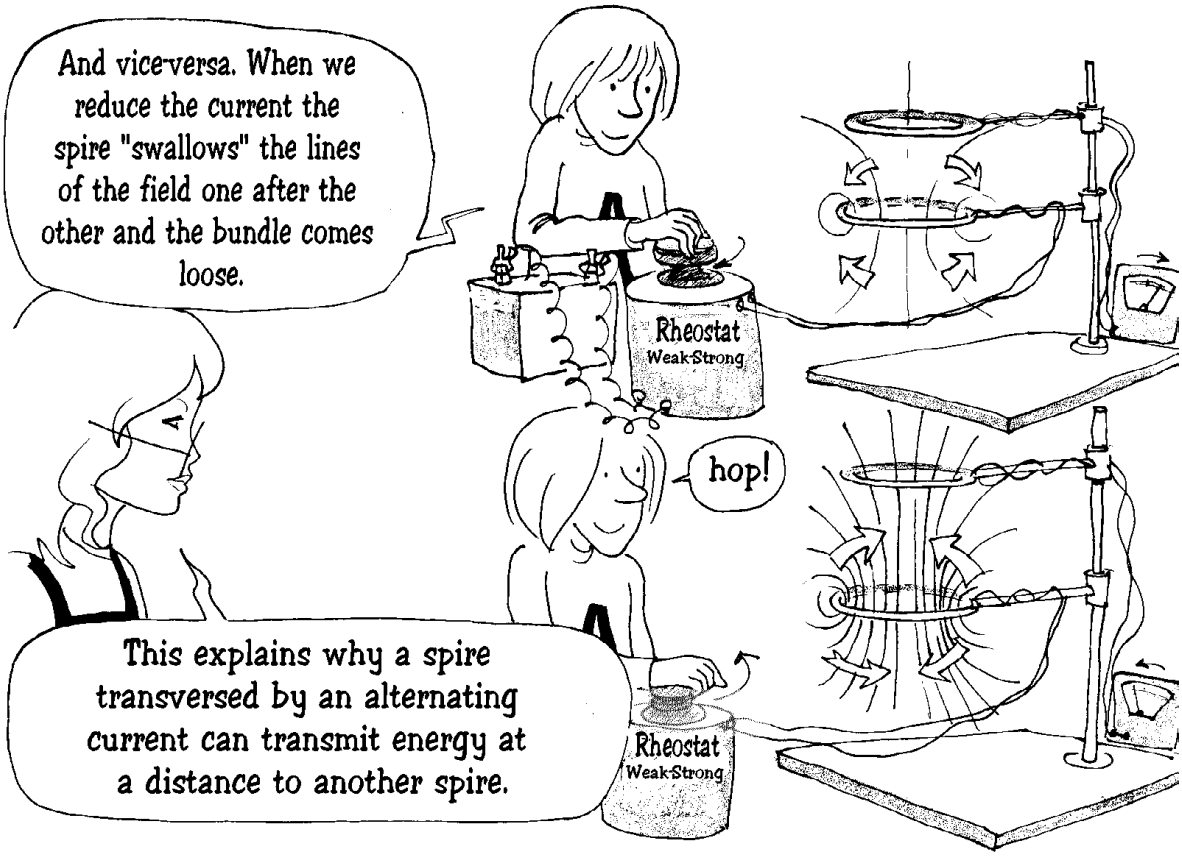




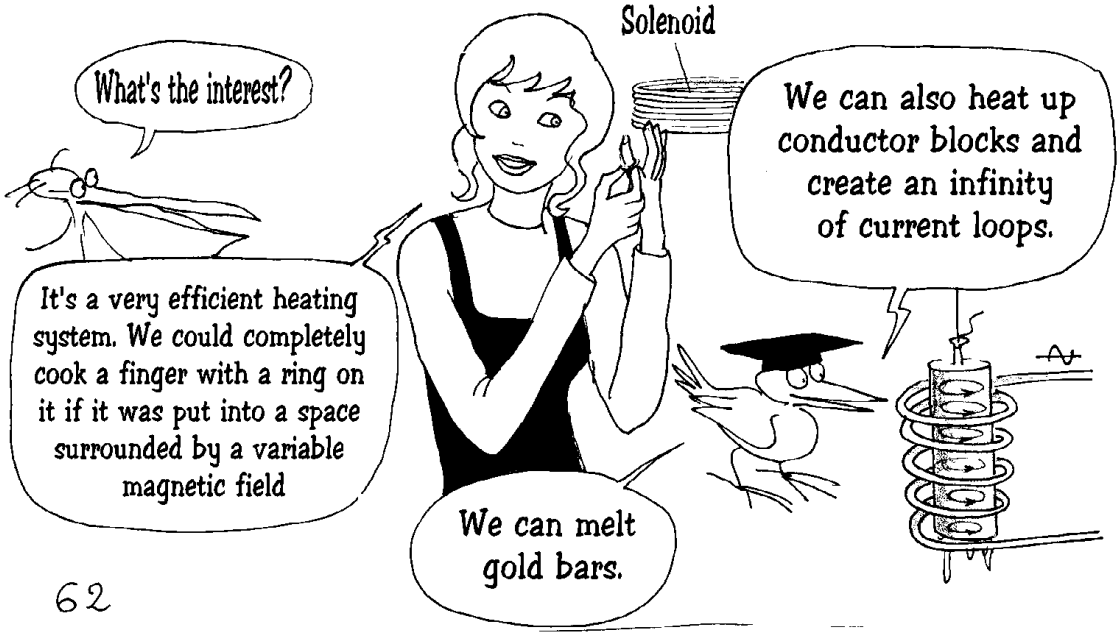
So here is our first alternating current generator.

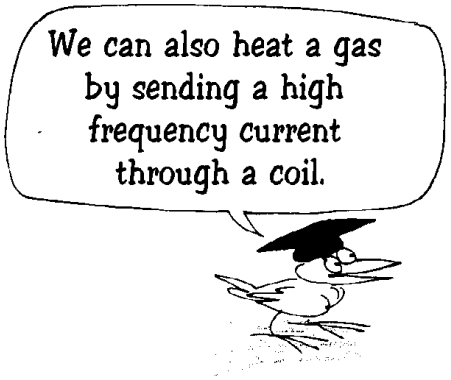

Heavens ! whatever's all that?
bleb
bleb
bleb
N
S
You know what Higgins is like. He was just applying the principle of the generator.
Instead of moving the spire he's moving the magnet.
N
S
shtonk

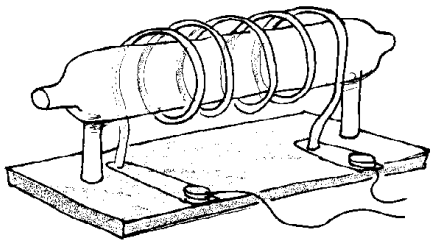

As we're producing alternating current by moving one or several magnets in front of a spire, I've invented this TWIGGO-GENERATOR. I've attached the magnets to flexible rods,twigs...
...when I let them go they separate and come back together alternately and produce an alternating current in the spire.
OK. This machine converts to electric energy the energy held in the twigs, and so what?
It reproduces what happens when you increase the current passing through the spire. It's as if new force lines are created on its surface which "compress" the old ones, like in a bundle of twigs.

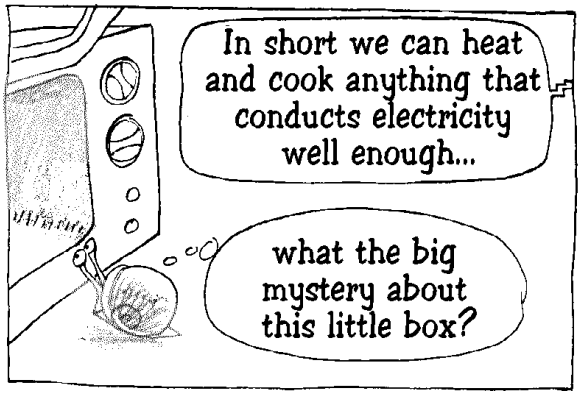

And vice-versa. When we reduce the current the spire "swallows" the lines of the field one after the other and the bundle comes loose.
Rheostat
Weak Strong
hop!
This explains why a spire transversed by an alternating current can transmit energy at a distance to another spire.
Rheostat
Weak Strong

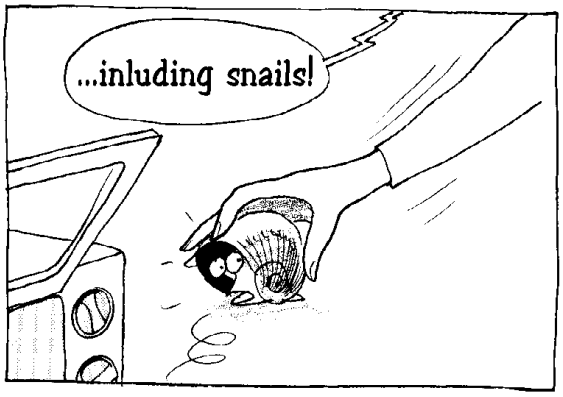
HF HEATING


Solenoid
What's the interest?
It's a very efficient heating system. We could completely cook a finger with a ring on it if it was put into a space surrounded by a variable magnetic field
We can also heat up conductor blocks and create an infinity of current loops.
We can melt gold bars.

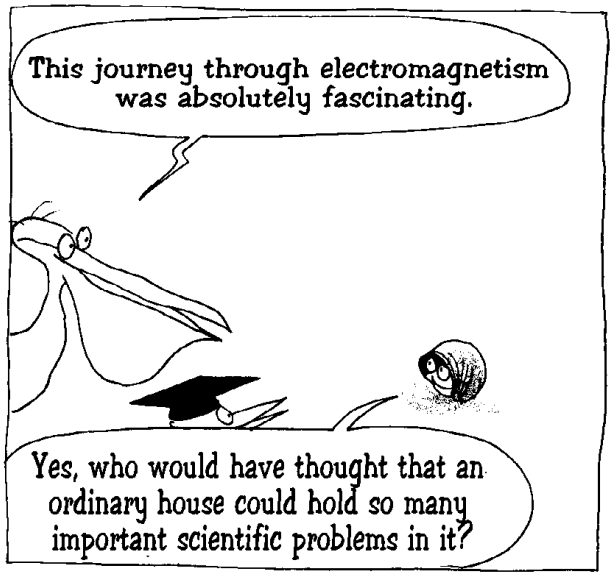

We can also heat a gas by sending a high frequency current through a coil.

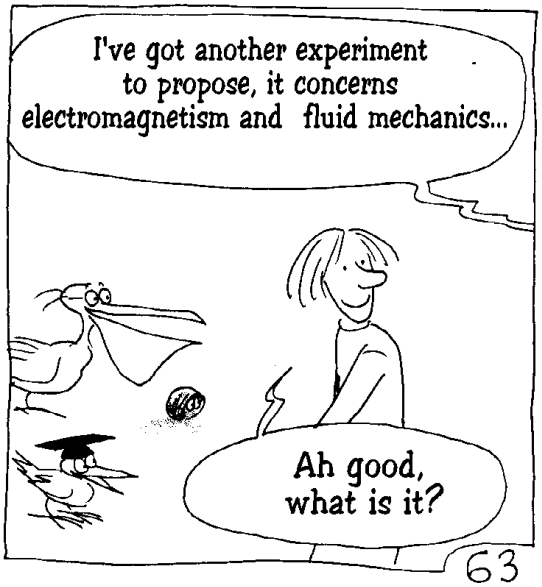



In short we can heat and cook anything that conducts electricity well enough...
what the big mystery about this little box?


...inluding snails!

EPILOGUE


This journey through electromagnetism was absolutely fascinating.
Yes, who would have thought that an ordinary house could hold so many important scientific problems in it?


I've got another experiment to propose, it concerns electromagnetism and fluid mechanics...
Ah good, what is it?


RRRRRR